doi:10.1038/nature22997

Tundra uptake of atmospheric elemental mercury drives Arctic mercury pollution

Daniel Obrist[1,2], Yannick Agnan[2,3], Martin Jiskra[4], Christine L. Olson[2], Dominique P. Colegrove[5], Jacques Hueber[5], Christopher W. Moore[2,6], Jeroen E. Sonke[4] & Detlev Helmig[5]

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

of

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1029/2017GB005840

Mercury in Active-Layer Tundra Soils of Alaska: Concentrations, Pools, Origins, and Spatial Distribution

C. Olson[1], M. Jiskra[2], H. Biester[3], J. Chow[1], and D. Obrist[1,4]

[1]Desert Research Institute, Reno, NV, USA, [2]Geosciences Environment Toulouse, CNRS, Toulouse, France, [3]Environmental Geochemistry, Technische Universität Braunschweig, Braunschweig, Germany, [4]Department of Environmental, Earth and Atmospheric Sciences, University of Massachusetts, Lowell, MA, USA

Ex. 4 CBI Copyright

spatial distribution. *Global Biogeochemical Cycles*, *32*, 1058–1073. https://doi.org/10.1029/2017GB005840

Received 14 NOV 2017
Accepted 6 JUN 2018
Accepted article online 19 JUN 2018
Published online 20 JUL 2018

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

10.1029/2017GB005840

Ex. 4 CBI Copyright

EARTHJUSTICE

March 29, 2022

VIA EMAIL

Alaska Department of Environmental Conservation
Division of Water
Wastewater Discharge Authorization Program/401 Certification
555 Cordova Street
Anchorage, AK 99501-2617
E: dec-401cert@alaska.gov

Re: Donlin Gold Mine Certificate of Reasonable Assurance

Dear Alaska Department of Environmental Conservation,

Pursuant to the Order Granting Interlocutory Remand in *Orutsararmiut Native Council v. Alaska Department of Environmental Conservation*, No. 3AN-21-06502CI (Dec. 29, 2021), Orutsararmiut Native Council (ONC) submits these comments on the new draft studies commissioned by Donlin Gold LLC (Donlin) to evaluate the impacts of the proposed gold mine on stream temperatures[1] and mercury concentrations.[2]

For purposes of this letter, the following Kuskokwim-Yukon area tribes join ONC in these comments: Chevak Traditional Council, Chuloonawick Native Village, Native Village of Eek, Kasigluk Traditional Council, Native Village of Kwigillingok, Native Village of Nunapitchuk, and Tuluksak Tribal Council. ONC and the other tribes share common concerns about the impacts of the proposed gold mine on water quality, fish habitat, and subsistence uses. These concerns have prompted nearly unanimous opposition to the proposed mine among the tribal governments of the region, as reflected in the resolution of the Association of Village Council Presidents.[3] If the Department of Environmental Conservation ("the Department" or "ADEC") upholds the Certificate of Reasonable Assurance for the proposed

[1] BGC Engineering Inc., "Analysis of Crooked Creek Stream Temperature" (Draft, Sept. 28, 2021) (BGC 2021).
[2] Ramboll US Consulting, Inc., "Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis" (Oct. 22, 2021) (Ramboll 2021).
[3] *See* Exhibit 3 (Association of Village Council Presidents, A Resolution Opposing the Further Development and Near Future Operation of the Donlin Creek Gold Mine, Resolution 19-09-10 (Sept. 2019) & K. Shallenberger, *AVCP delegates pass resolution against Donlin Gold Mine*, ALASKA PUBLIC MEDIA (Sept. 27, 2019)).

mine, the tribes of the Kuskokwim and Yukon River basins will have to live with the impacts forever, long after the mining company is gone. Donlin's draft reports fall far short of the assurance needed to support such a consequential decision.

I. Introduction and summary.

The draft studies confirm that there is no "reasonable assurance"[4] that the proposed mine will comply with Alaska's water quality standards for temperature or mercury. Both draft studies rely on models to estimate the impacts of the proposed mine decades in the future. Both models—like any model—are simplified representations of the real world subject to multiple sources of uncertainty. Even with the best models using verifiable data, actual outcomes will normally vary within a range from a model's estimate. In the case of Donlin's models, these deviations could be substantial due to multiple sources of uncertainty.

Both of Donlin's models predict outcomes almost exactly at the applicable standard. Given the large range of potential deviation from those outcomes, the models provide no basis to believe that compliance is any more likely than non-compliance. There is no "reasonable assurance" that either standard will be met.

Neither model is conservative. To the contrary, they were designed to eliminate the conservative assumptions of the Final Environmental Impact Statement (FEIS) for the Donlin Project, and they make simplifying assumptions that ignore real-world conditions that would increase the risk of violations. Thus, the Department must not treat them as risk-averse screening models.

Neither of the draft reports attempts to quantify or characterize the degree of uncertainty associated with the projections. Further, neither of them has been subject to normal analytical tools recommended to evaluate the results of a model, most importantly sensitivity analysis, uncertainty analysis, alternative scenarios, and peer review. In the absence of these analyses, the Department must assume a particularly high degree of uncertainty associated with these models and, therefore, a lack of reasonable assurance of compliance.

This lack of reasonable assurance is inherent in the models and would be apparent even if one assumes they were well-designed and supported by ample data. When one considers the shortcomings of the models, it is even more clear they provide no reasonable assurance of compliance. A leading expert in each of the two fields has reviewed the draft reports and found multiple sources of bias, suggesting that real-world outcomes are likely to be even worse than projected in the models.

---

[4] 40 C.F.R. § 121.2(a)(3) (2019).

While there is no reasonable assurance of compliance with either the temperature or mercury standard, the likelihood of complying with both is lower still. It is roughly like needing to flip heads in two consecutive coin tosses. The law requires a single finding of reasonable assurance as to all standards.

For these and other reasons, the Department should approach Donlin's new draft studies warily. They were prepared hastily, in response to litigation, with a strong incentive by Donlin to demonstrate compliance. Even with that strong incentive, the best they could do was to generate outcomes meeting the relevant standards by the thinnest of margins, revealing a high risk of non-compliance. By contrast, the FEIS underwent lengthy, multi-agency review, contains nuanced cautions about uncertainty wholly lacking from Donlin's rushed new reports, and finds significant risk of violating the temperature and mercury standards. In short, Donlin has failed to carry its burden of demonstrating reasonable assurance of compliance.

The Department should find that there is no reasonable assurance of compliance with water quality standards and rescind the Certificate of Reasonable Assurance.

II. Because the outcomes are so close to the standards, the inherent uncertainty of models precludes a finding of reasonable assurance.

Donlin's draft reports do not demonstrate reasonable assurance of compliance with temperature or mercury standards, because they are based on models with estimated outcomes almost exactly at the applicable standards. They are attempting to predict responses to conditions that do not yet exist and cannot be verified until the mine is built and operated decades in the future. Given the inherent uncertainty of models and outcomes on the boundary of non-compliance, the likelihood of compliance would be no better than that of non-compliance, even if the models were well designed.

Regulations of the U.S. Environmental Protection Agency (EPA) place the burden on Donlin as the applicant to provide information sufficient to support a finding of reasonable assurance.[5] Donlin's draft reports do not do so here. To the contrary, because they produce outcomes so close to the applicable standards and with such a high degree of uncertainty, they demonstrate that there is no reasonable assurance of compliance.

---

[5] *Id.* § 121.2(a)(2), (3) (2019). *See also* R. 9611, 9623 (EPA, Clean Water Act Section 401 Water Quality Certification at 18, 30 (2010)) ("an applicant must demonstrate that the proposed activity and discharge will not violate or interfere with the attainment of any limitations or standards identified in §401(a) and (d)"), ("The burden of proof remains on the applicant to show that the requirements of the [Clean Water Act] have not been and will not be violated as a result of the activity."). Record citations in this letter are to the agency record transmitted by the Department to the Superior Court in this matter on August 2, 2021.

A. Models are imperfect simplifications of reality.

Even the best model is an imperfect simulation of the real world, subject to error and uncertainty. As the aphorism goes, "all models are wrong, but some are useful."[6]

EPA has published a detailed guidance on the development, evaluation, and application of environmental models like those created by Donlin's contractors.[7] In it, EPA adopts the National Research Council's definition of a model: "A simplification of reality that is constructed to gain insights into select attributes of a particular physical, biological, economic, or social system."[8]

EPA repeatedly emphasizes the uncertainty associated with models and cautions users to treat them accordingly. Again quoting the National Research Council, the guidance explains: "Models will always be constrained by computational limitations, assumptions and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions."[9] EPA concludes, "The challenge facing model developers and users is determining when a model, despite its uncertainties, can be appropriately used to inform a decision."[10] In the succinct words of another paper, decision-makers should not use models as "truth machines."[11]

The FEIS cautions against mechanistic reliance on models, specifically in the context of the groundwater model on which both Donlin's temperature model and mercury model rely. "As is common with models of this type, . . . the model is used to simulate conditions (such as dewatering the mine pit) that do not currently exist. The amount and uncertainty of inaccuracies of these simulations are difficult to gauge."[12]

---

[6] *See* W. Wagner *et al.*, "Misunderstanding Models in Environmental and Public Health Regulation," 18 N.Y.U. ENVTL. L.J. 293, 297 (2010) (Wagner *et al.*) (quoting G. Box & N. Draper, "Empirical Model-Building and Response Surfaces," 424 (1987)).

[7] Exhibit 4 (EPA, Guidance on the Development, Evaluation, and Application of Environmental Models (Mar. 2009) (EPA Guidance), https://www.epa.gov/measurements-modeling/guidance-document-development-evaluation-and-application-environmental-models).

[8] *Id.* at 9.

[9] *Id.* at 27; *see also id.* at 12 ("models are based on simplifying assumptions and cannot completely replicate the complexity inherent in environmental systems."); *id.* at 28 ("Because every model contains simplifications, predictions derived from a model can never be completely accurate and a model can never correspond exactly to reality.").

[10] *Id.* at 27.

[11] Wagner *et al.* at 295.

[12] R. 16967 (FEIS at 3.6-23) (citation omitted).

B. Both of Donlin's draft models generate estimated outcomes almost exactly at the applicable standard, providing no assurance of compliance.

The inherent uncertainty of the models is particularly important here, because both of Donlin's new draft models generate outcomes almost exactly at the applicable standard. If the inevitable deviations from the models' estimates are even slightly on the high side, the mine will violate the standards. Even if one assumes for the sake of argument that the models are well-designed, unbiased, and supported by ample data, given the inherent uncertainty of models and the near-miss outcomes, it is essentially a coin toss whether operation of the mine in the real world would comply with either standard.

1. The draft temperature model predicts temperatures within less than one degree Fahrenheit of the limit.

For temperature, the BGC Engineering draft model predicts outcomes within 0.6°F of the standard. Alaska has set water quality standards of 55.4°F (13°C) for egg and fry incubation and spawning.[13] The draft model predicts that mine operations, by withdrawing colder surface water and groundwater from the stream systems, will raise temperatures to 54.8°F in Crooked Creek at American Creek and 54.5°F in Crooked Creek at Crevice Creek.[14] These outcomes are just 0.6°F and 0.9°F below the standard, respectively.

Therefore, even if one accepts the model results without considering potential errors, omissions, or biases, the model provides no reasonable assurance of compliance with the standard. If the model is off by less than a degree, or if a future year is a degree warmer than the July 2005 comparison, the mine would violate the standard. Those are extremely small deviations from inherently imperfect estimates, providing no reasonable assurance that the mine will comply with the standard. Donlin has not carried its burden to demonstrate reasonable assurance.

2. Any mercury concentrations greater than those predicted in the draft model would violate the standard.

Donlin's new draft mercury model demonstrates no greater assurance of compliance than the temperature model. Because the waters near the mine have naturally elevated mercury levels and sometimes exceed the chronic criterion for mercury under pre-mine conditions, any non-trivial increase in mercury concentrations in the streams presents a significant risk of new violations of the chronic standard for aquatic life.

---

[13] 18 AAC 70.020(b)(10)(C).

[14] BGC 2021 at 23.

The mine would be developed in a "mercury belt" with high concentrations of mercury occurring naturally in the environment.[15] In samples taken from streams near the proposed mine from 2005 to 2015, 14 percent—80 out of 564 samples—exceeded 12 ng/L, the standard for a four-day chronic exposure to mercury.[16] Three of the samples had concentrations more than ten times the criterion.[17] Though they did not sample for four days continuously, the exceedances were "widespread" and clustered at certain times of the year and conditions.[18] "[M]ercury concentrations are generally higher during spring flow and storm flow conditions," and spikes may occur "due to precipitation and localized rock weathering conditions."[19]

The FEIS concluded, "These data suggest that existing concentrations of total mercury in surface water are sometimes elevated above the chronic criterion at locations throughout the Mine Site area…."[20] This point has never been disputed by the Department or by Donlin, and Donlin's new draft model by Ramboll US Consulting does not challenge that point.

Because the streams likely exceed the chronic criterion at times already, even a small increase in mercury concentrations would risk more violations, precluding any finding of reasonable assurance. Using conservative assumptions, the FEIS predicted a 40% increase in mercury concentrations,[21] which if true would certainly lead to substantial and frequent violations.[22] For these reasons, the only way Donlin could demonstrate reasonable assurance of compliance with the mercury standard would be if the company were to show that the mine would cause no significant increase in mercury concentrations in local waters.

The Ramboll draft mercury model seeks to achieve this result by eliminating the principal conservative assumptions of the FEIS.[23] By so doing, the model generates outcomes showing a tiny increase (0.8%) in Donlin Creek and tiny decreases at two locations in Crooked

[15] R. 17749, 17269 (FEIS at 3.13-28, 3.8-35).
[16] R. 17040 (FEIS at 3.7-29); *see* 40 C.F.R. § 131.36(b)(1), row "8 Mercury," column B2, note "d." Because EPA has not approved Alaska's proposed aquatic life criteria for mercury, the EPA standard applies. R. 17017 (FEIS at 3.7-6).
[17] R. 17040 (FEIS at 3.7-29).
[18] R. 17163 (FEIS at 3.7-152).
[19] R. 17040 (FEIS at 3.7-29).
[20] R. 17162 (FEIS at 3.7-151).
[21] *Id.*
[22] R. 17170 (FEIS at 3.7-159) ("While the mean value is below the chronic [criterion] of 12 ng/L, the range of baseline data . . . indicates that this criteria [sic] would be exceeded in some areas within the 20-mile radius of the Mine Site some of the time."); *see also* R. 17162 (FEIS at 3.7-151) (mining operations "would likely cause an increase in exceedances of the 12 ng/L chronic criterion.").
[23] Ramboll 2021 at ES-1.

Creek (-1.6% at the Kuskokwim and -2.0% at Crevice Creek).[24] The report concludes that the projected increase at Donlin Creek is too small to produce any increase in the number of samples exceeding the chronic standard.[25]

As with the temperature model, these outcomes are far too close to the standard to provide any assurance of compliance when considering the inherent uncertainty. If any of the model's projections are low by even a small amount, the mine would cause an increase in the number and magnitude of exceedances over those that occur naturally, violating the standard. Given the inherent uncertainty in the model, it provides no reasonable assurance of compliance. Donlin has not carried its burden.

C. Donlin's draft models are not conservative.

Faced with the inherent uncertainty of models, one way to make sound use of them is to design them with conservative, risk-averse assumptions, so that errors would occur on the side of safety.[26] Donlin's contractors did not do that here. Rather, they attempt to demonstrate bare compliance with the applicable standards by omitting or eliminating conservative assumptions, resulting in a high risk of violating the standards.

1. The draft temperature model ignores the likelihood of warmer stream temperatures in the future from several causes.

The BGC Engineering draft temperature model omits real-world conditions that would result in higher temperatures, and it is therefore not conservative. It is a simple mixing model: It merely estimates the temperatures and volumes of the water entering the stream from different sources (based on just six years of data) and adds them up.[27] This simple approach misses several real-world considerations that would raise temperatures. ONC emphasizes three of them here.

First, the draft model is based on only six years of overlapping historic data and makes projections based on the warmest month in that period, July 2005.[28] Implicit in this is that the warmest month in the 27-year life of the mine will be no warmer than July 2005, but that is highly unlikely. With so many more years of operation than of data, it is likely there will be warmer years and correspondingly warmer stream temperatures. By relying only on a highly

---

[24] *Id.* at 3-28. The model shows much more substantial reductions in American and Anaconda creeks, but that is because those streams are mostly eliminated by the mine.
[25] *Id.* at 3-31.
[26] *See, e.g.*, Exhibit 4 at 30 (EPA Guidance).
[27] BGC 2021 at 5, 11.
[28] *Id.* at 5, 15.

limited data set, the draft temperature model fails to make projections for foreseeably higher temperatures.[29]

Temperature records from the National Weather Service (NWS) support the conclusion that there have been and likely will be months warmer than July 2005. The nearest station with temperatures reported online is Bethel. In Bethel, as at Crooked Creek, July 2005 had the warmest mean average temperatures among the months with data from Crooked Creek: 2005-2009 and 2011.[30] This confirms that Bethel and Crooked Creek experience similar weather patterns. However, looking at just a few additional years of data from Bethel, there were five months with average temperatures warmer than July 2005: two of them earlier (July and August 2004), and three of them later (July and August 2016, and July 2019).[31] The same pattern holds true for Bethel's mean maximum temperatures: July 2005 was highest among the years in the BGC model, but there were five months with higher mean maximums in other years, both earlier and later (July and August 2004, June 2015, July 2016, and July 2019).[32] It is all but certain that there have similarly been warmer months at Crooked Creek and that there will be more in the future.

Stream temperature records farther downstream in Crooked Creek also confirm this conclusion. Federal agencies maintain stream temperature records from Crooked Creek at the Crooked Creek Airport, downstream of the sites modeled by Donlin.[33] While the warmest Crooked Creek temperature modeled by Donlin based on July 2005 readings was 52.6°F (11.4°C),[34] the downstream site database includes 20 readings higher than that, all but two of which were in 2018 and 2019.[35] The highest was 54.7°F (12.6°C), just 0.7°F below the standard.[36] On the basis of these high readings, the Department has proposed to list Crooked Creek on Alaska's impaired water body list for temperature in Category 3, "Waters for which there is not

---

[29] *See also* Exhibit 6 at 2 (T. Myers, "Surface Water Temperature Effects of the Proposed Donlin Project" (Nov. 24, 2021)) (Myers 2021) ("BGC presents no analysis as to the frequency that the low flows or high temperatures observed in summer 2005 have occurred so the predictive power of that knowledge is limited.").

[30] BGC 2021 at 5; Exhibit 8 at 1 (NWS, Bethel Temperature Data 2000-2022) (NWS 2022).

[31] Exhibit 8 at 1 (NWS 2022).

[32] *Id.* at 2.

[33] Exhibit 7 (National Water Quality Monitoring Council, Water Quality Portal, excerpt for Crooked Creek, Alaska (USGS-15304010)) (Alaska waters database). This exhibit is an excerpt from a massive federal database available at https://www.waterqualitydata.us/. The Department formerly posted the Alaska waters in an Excel spreadsheet on its website. *See* Exhibit 2 at 3 (ADEC, 2022 Draft Integrated Report, Questions and Answers). The excerpt in Exhibit 7 includes just the temperature readings from Crooked Creek (USGS-15304010), sorted from warmest to coldest.

[34] BGC 2021 at 15, 23.

[35] Exhibit 7 (Alaska waters database).

[36] *Id.*

enough information to determine their status."[37] By withdrawing colder surface water and groundwater from Crooked Creek at the mine site upstream, the mine would only warm the water further. If there is not enough information to determine whether Crooked Creek downstream of the mine currently complies with the temperature standard, then it is not logically possible to support a finding of "reasonable assurance" that the proposed mine will not cause violations.

The second respect in which the draft temperature model is not conservative is that it fails to consider the effects of future climate change. As discussed, the model has insufficient data to reflect even recent recorded warmer temperatures. Due to climate change, temperatures will be warmer in the future, which could affect stream temperatures in two ways: "It could decrease flows during warm, dry periods and increase the air temperature and therefore the flux of heat from the air to the water. Both would increase the stream temperature."[38]

While climate change will generally warm the whole planet, temperature increases are expected to be greater on average at the high latitudes of the proposed mine. The U.S. Global Change Research Program predicts that the Yukon-Kuskokwim region will warm significantly over the course of this century.[39] At Crooked Creek, the projected average monthly temperature increases range between 3-7°F for 2030-2039 and 4-11°F for 2060-2069 under the low emissions scenario (RCP 4.5).[40] Under the high emissions scenario (RCP 8.5), the ranges are 3-9°F and 7-14°F, respectively.[41]

By failing to address future climate change, Donlin's draft temperature model overlooks foreseeably higher temperatures that would bump the mine's impacts well over the standard.

The third respect in which the model is not conservative is that, as a simple mixing model, it fails to consider thermal effects, *i.e.*, warming that may occur from atmospheric radiation and air temperatures warmer than the water. For example, the model assumes that the temperature of Crooked Creek just below American Creek (node Q3) will equal the temperature at Crooked Creek just above Anaconda Creek (node Q1), meaning that no

---

[37] Exhibit 1 at 2, 11 (ADEC, 2022 Draft Integrated Report, Fact Sheet (Jan. 24, 2022)).
[38] Exhibit 6 at 3 (Myers 2021).
[39] *See, e.g.*, Exhibit 9 at 16, Fig. 26.1 (U.S. Global Change Research Program, Fourth National Climate Assessment, Volume II: Impacts, Risks, and Adaptation in the United States (Rev. Mar. 2021)) (showing projected average annual temperatures rising between 6-8°F under the lower Representative Concentration Pathway (RCP) 4.5 scenario and 10-12°F under the higher RCP 8.5 scenario by 2070-2099).
[40] *See* Exhibit 10 at 1 (University of Alaska Fairbanks, Scenarios Network for Alaska, Community Climate Charts, Crooked Creek (Qipcarpak), Alaska, https://snap.uaf.edu/tools/community-charts (last accessed Feb. 3, 2022)).
[41] *See id.* at 3.

warming would take place as the stream flows between these tributaries.[42] The distance between the intersections of these tributaries with Crooked Creek is about three miles as the crow flies,[43] which is about eight stream miles on this winding creek.[44] On a warm day, over a distance of eight miles, there will clearly be some warming from the ambient air.[45]

The draft temperature model claims to make but one conservative assumption: that the water removed from the creek by the dewatering wells would be as cold as average groundwater.[46] To the extent this assumption is conservative, it does not offset the decidedly non-conservative omissions described above.

Because Donlin's draft temperature model predicts temperatures less than one degree Fahrenheit below the standard, even a slightly higher temperature from any of these three causes—unmeasured warmer years, climate change, and thermal effects—could easily bump the stream temperatures over the standard. Taken together, violations are a near certainty. Thus, the draft model is not conservative, and there is no "reasonable assurance" that the mine will comply with the temperature standard. Donlin has not carried its burden of demonstrating reasonable assurance of compliance.

2. The draft mercury model eliminates conservative assumptions and aggressively seeks to minimize potential mercury emissions.

Nor is the Ramboll draft mercury model conservative. To the contrary, its central stated purpose is to eliminate the principal conservative assumptions of the model used in the FEIS,[47] to be "more accurate" rather than risk-averse.[48] While Ramboll claims to make a few remaining conservative assumptions among the countless inputs to the complex, multi-part model,[49] the dominant feature of the model is an aggressive attempt to downplay estimated emissions of mercury. Compared to the FEIS, it claims a 72% decrease in processing emissions and a 73% decrease in tailings emissions, which are by far the two largest sources of emissions from the mine.[50] As discussed further below, both revised calculations are implausibly low.

---

[42] BGC 2021 at 10, 11.
[43] *See id.* at 6.
[44] The FEIS reports that this segment, called CR-R4, *see* R. 17730 (FEIS Fig. 3.13-1), has a sinuosity of 2.7. R. 017734 (FEIS at 3.13-13, Tbl. 3.13-1). Three miles in a straight line thus includes 8.1 stream miles (3 x 2.7 = 8.1).
[45] *See* Exhibit 6 at 3 (Myers 2021).
[46] BGC 2021 at 12.
[47] Ramboll 2021 at ES-1, 2-2, 3-9 to 3-10, 3-13 n.15.
[48] *Id.* at ES-1.
[49] *Id.* at 3-12 (disregarding the use of settling reagents in tailings water), 3-20 (disregarding in-pit retention of fugitive dust), 3-28 (assuming effluent will contain the maximum allowed mercury level).
[50] *Id.* at ES-1 & ES-2, Tbl. ES-1.

It is potentially misleading for Ramboll to state that it was "conservative" to use the years of peak projected mercury emissions from the tailings disposal site and fugitive dust.[51] The law requires considering peak conditions. Alaska's water quality standards apply on every day of every year for the life of the mine and beyond.[52] While the Department may grant short-term variances under certain conditions,[53] it has not done so here and Donlin has not requested one. In the absence of a variance, any model must therefore make projections for the point in time at which mercury concentrations would be expected to be greatest. The failure to do so would offer no reasonable assurance of compliance when concentrations are highest. Modeling for this legal requirement is therefore not particularly "conservative." And because the model predicts compliance by only the thinnest of margins at that time, the uncertainty inherent in the model precludes a finding of reasonable assurance. Donlin has failed to carry its burden.

D. The draft models lack basic analysis to assess reliability in the face of uncertainty.

Both of Donlin's draft models make the elementary mistake of presenting each outcome as a single, highly precise number—such as 54.8°F at the American Creek inflow[54] and a 0.8% increase in mercury in Donlin Creek[55]—with no attempt to characterize the degree of uncertainty. It is simply not possible to predict temperatures to the nearest 0.1°F or mercury concentrations to the nearest 0.1% in streams 30 years in the future following massive alterations to complex natural systems. By asserting such outcomes, both models imply a measure of precision far beyond their capability, and indeed beyond the capability of any model.

Neither report discloses even such basic measures of uncertainty as standard deviation, standard error, or confidence intervals.[56] And those measures alone would not be sufficient, even if they had been included: "Simply putting error bars around the final result is inadequate in capturing the full uncertainties and complexities of models."[57] Nor does either model present

---

[51] *Id.* at 3-14, 3-20.
[52] *See generally* 18 AAC 70.010.
[53] 18 AAC 70.200, .205.
[54] BGC 2021 at 15.
[55] Ramboll 2021 at 3-31.
[56] *See, e.g.*, Exhibit 4 at 83-84 (EPA Guidance).
[57] Wagner *et al.* at 352.

alternative scenarios, another recommended tool.[58] Both models have multiple inputs that are estimates of future values, each of which is subject to its own standard deviations, standard errors, and confidence intervals that would affect the model's ultimate outcome, but the reports disclose little or none of this. By presenting a single, implausibly precise number as the definitive outcome, both draft reports present their models as "truth machines," a practice cautioned against by EPA[59] and other commentators.[60]

EPA's modeling guidance establishes best practices to evaluate the uncertainty inherent in models for environmental decision-makers. These safeguards include corroboration, sensitivity analysis, uncertainty analysis, and peer review,[61] none of which were undertaken, at least in any meaningful way, for either of Donlin's draft reports. Of course, corroborating the models with data from actual conditions is impossible, since those conditions will exist only after the massive excavations, diversions, pumping, filling, processing, and discharges associated with the mine. In these circumstances, the other tools—including sensitivity analysis, uncertainty analysis, and peer review—are even more important.[62]

An example of better treatment of uncertainty is the discussion of the groundwater flow model in the FEIS. It acknowledges the unknown data, tests different scenarios with different outcomes, and cautions readers "that the model results showing impacts to Crooked Creek should be regarded as uncertain, and that the analysis of project effects should include scenarios other than the base case (e.g., the sensitivity analyses described above)."[63] Neither of Donlin's new draft reports include any such evaluation or disclosure, even though both reports rely on that very model and countless other uncertain inputs.

---

[58] *See* Exhibit 4 at 39 (EPA Guidance) ("To facilitate communication of model uncertainty, the committee recommends using hybrid approaches in which unknown quantities are treated probabilistically and explored in scenario-assessment mode by decision makers through a range of plausible values."); Wagner *et al.* at 352 ("[M]odels should be created with a variety of assumptions and scenarios that illustrate the differences these assumptions and choices make for policymakers.").

[59] Exhibit 4 at 27 (EPA Guidance) ("Models . . . can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions.").

[60] Wagner *et al.* at 295-96.

[61] Exhibit 4 at 29 (EPA Guidance).

[62] *Id.* at 37 ("In many cases, collecting independent datasets for formal model corroboration is extremely costly or otherwise unfeasible. In such circumstances, model evaluation may be appropriately conducted using a combination of other evaluation tools discussed in this section.").

[63] R. 16980-82 (FEIS at 3.6-36 to 3.6-38).

1. The draft temperature model contains insufficient evaluation of uncertainty.

The BGC Engineering draft temperature model includes just one sensitivity analysis on a single variable in the model: the temperature of the effluent discharge.[64] Testing a single input in the model is not sufficient as a meaningful sensitivity analysis, because it does not enable the user to compare and evaluate the model's multiple sources of uncertainty: "Sensitivity analysis is recommended as the principal evaluation tool for characterizing the most and least important sources of uncertainty in environmental models."[65] It should be used "early and often."[66] To test just a single input, then, largely misses the point.

To its credit, the draft temperature model also includes two paragraphs identifying multiple sources of uncertainty associated with the model and acknowledging the model does not account for them.[67] This is an important acknowledgement, and it reinforces the conclusion that the outcome should be treated as subject to a high, though un-evaluated, degree of uncertainty.

Even without such basic analytical tools as standard deviations, confidence intervals, error bars, sensitivity analysis, uncertainty analysis, alternative scenarios, or peer review, the draft temperature report makes clear that there is no reasonable assurance the standard will be met. As discussed above, the projected temperatures are almost exactly at the standard, despite a model design disregarding important factors that would result in higher temperatures. Rigorous evaluation of the draft model would only confirm the conclusion that there is no reasonable assurance of compliance.

Dr. Tom Myers—a consulting hydrologist with decades of experience assessing impacts of mines, including mine dewatering and groundwater modeling[68]—tested the sensitivity of the model to changes in just a few of the model inputs. He demonstrates that even small, plausible changes in the inputs to the BGC Engineering draft model would lead to violations of the standard. The draft model recognizes that the proposed mine's tailings facility would eliminate most of the flow from Anaconda Creek (Q2).[69] But if the flow drops to zero (as is possible given uncertainties in future streamflows), the tributary's cooling effect on Crooked Creek would disappear and raise the temperature in Crooked Creek (Qa) to 54.9°F, violating the standard.[70] The draft model assumes (with no data) that effluent temperatures from the wastewater treatment facility will not be high enough to affect the stream, but if discharges are much

---

[64] BGC 2021 at 18.
[65] Exhibit 4 at 39 (EPA Guidance).
[66] *Id.* at 16.
[67] BGC 2021 at 22.
[68] Exhibit 6 at 7-18 (Myers 2021).
[69] BGC 2021 at 2, 11.
[70] Exhibit 6 at 4 (Myers 2021).

warmer than assumed, the standard would be violated.[71] If thermal effects assumed not to exist by the draft model warm Crooked Creek just a couple degrees between tributaries, the standard would be violated.[72] If the stream temperature in Anaconda Creek (Q2) is less than a degree warmer than the modeled temperature, it would warm Crooked Creek (Qa) above the standard.[73] If the background water temperature is less than a degree higher than in July 2005, the temperature standard would be violated.[74]

For these reasons, Myers concludes that "there are so many assumptions necessary to keep the temperatures from exceeding the standards that it is likely that future stream temperatures will exceed the standards, especially as climate change increases the background temperatures that the mine will only increase with its effects."[75] There is no reasonable assurance that the proposed mine will comply with the temperature standard. Donlin has not carried its burden of demonstrating reasonable assurance of compliance.

Dr. Myers' report is attached to this letter as Exhibit 6. ONC incorporates it by reference and requests that the Department provide a complete response to it as if set out here in its entirety.

2. The draft mercury model contains insufficient evaluation of uncertainty.

While the draft temperature model at least acknowledges sources of uncertainty, the Ramboll draft mercury model concedes no such limitations. Nor does it contain any sensitivity analysis or any of the other safeguards recommended by EPA or other commentators. This is not for lack of need. The mercury model is much more complex than the temperature model and has correspondingly many more sources of uncertainty. The FEIS acknowledges, correctly, that "[p]redicting changes in mercury concentrations in aquatic systems is challenging…."[76]

The draft mercury model is a vastly more ambitious undertaking than the temperature model. While the temperature model simply adds up the estimated temperatures and volumes of different inputs to the stream system, the mercury model attempts to capture the effects of countless inputs from diverse natural and mining-induced physical, chemical, and thermal processes. The Ramboll draft model: estimates the mercury concentrations in the ore, the pit and the waste rock;[77] estimates the resulting fugitive gas emissions, stack emissions, and fugitive dust emissions, including wind erosion, from dozens of individual sources at the mine

---

[71] *Id.* at 3, 5.
[72] *Id.* at 6.
[73] *Id.*
[74] *Id.*
[75] *Id.*
[76] R. 17162 (FEIS at 3.7-151).
[77] Ramboll 2021 at 2-3, 3-16 to 3-17.

(*see* Appendix A hereto);[78] estimates the particle size distribution of the dust sources;[79] estimates the mercury retention rate in the soils, relying on lake sediments extrapolated to a stream system and on data from ecoregions deemed similar to the Crooked Creek watershed;[80] estimates mercury sources in surface waters by geochemical fingerprinting deduced from mercury-to-aluminum ratios;[81] estimates upstream streamflows relying in part on data from the CCAK monitoring station;[82] estimates upstream mercury mass loading in the stream also based on data from the CCAK site;[83] estimates baseline atmospheric deposition and geologic loading of mercury;[84] estimates reductions in mercury mass loading due to diversions of American and Anaconda creeks;[85] estimates mercury mass loading from the proposed wastewater treatment plant discharges;[86] and, from these estimates, calculates ultimate estimates of mass loading and mass balance at five monitoring stations in the Crooked Creek watershed, for both baseline conditions and mine operating conditions.[87]

At each of these many model inputs, estimates were made, though there is almost no disclosure of the standard deviations, standard errors, confidence intervals, or any other measures of the uncertainty each of these estimates contributes to the model's outcomes. For numerous inputs, the model relies on other models. Examples named in the Ramboll report include:

- EPA mercury modeling database for stack emissions from boilers, heaters, and incinerators.[88]
- ENVIRON modeling of atmospheric mercury deposition flux.[89]
- Streamflow and loading regression model to fill in gaps in data.[90]
- A conceptual terrestrial model of the ecosystem.[91]
- Least squares linear regression model for mercury retention rate in sediments.[92]
- CALPUFF model for particle sizes for dry and wet deposition.[93]

---

[78] *Id.* at 3-12 to 3-21.
[79] *Id.* at 3-10 to 3-11.
[80] *Id.* at 3-3 to 3-6.
[81] *Id.* at 3-6 to 3-9.
[82] *Id.* at 3-24 to 3-25 & ES-4, Fig. ES-2.
[83] *Id.* at 3-25.
[84] *Id.* at 3-26.
[85] *Id.* at 3-26 to 3-28.
[86] *Id.* at 3-28.
[87] *Id.* at 3-28 to 3-31.
[88] *Id.* at 3-18 to 3-19.
[89] *Id.* at 2-2, 3-9.
[90] *Id.* at 2-4, 3-24.
[91] *Id.* at 3-1, 3-26.
[92] *Id.* at 3-3.
[93] *Id.* at 3-11, 3-22.

- Geochemical modeling of the tailings filtrate water from the Feasibility Pilot Phase 2 study, which in turn relied on the Geochemist's Workbench model.[94]

With every new model and every estimated input, there is a new source of uncertainty. "[A]s models become more complex to treat more physical processes, their performance tends to degrade because they require more input variables, leading to greater data uncertainty."[95]

In a model with so many inputs, it is useful to begin sensitivity analysis early in model development "to identify the relative importance of model parameters."[96] Yet, if Ramboll performed any sensitivity analysis, it is not disclosed in the report. In fact, the report makes no attempt whatever to acknowledge, characterize, or evaluate the uncertainty. It contains not only no sensitivity analysis, but no standard deviations, no confidence intervals, no error bars, no alternative scenarios, no uncertainty analysis, and no peer review.

For these reasons, the Department must assume that the mercury estimates are subject to an extremely high degree of uncertainty. Given that the draft model produces outcomes that would comply with the chronic mercury standard by only the thinnest of margins, the inherent uncertainty compels the conclusion that there is no reasonable assurance of compliance. Donlin has not carried its burden to demonstrate otherwise.

This conclusion assumes that the model is otherwise well designed and based on supportable data. If it is not, then violations are even more likely.

E. The draft mercury model contains critical errors underestimating emissions.

Dr. Glenn Miller—Professor Emeritus at the University of Nevada, Reno with substantial experience in mercury contamination from mining[97]—evaluated the Ramboll draft mercury model and found that its predictions of mercury emissions from the mine are implausibly low. "To report that only 30 kg (66 lbs) (total from both thermal sources and fugitive emissions sources) would be released from the Donlin mine strains credibility."[98] He identifies two significant sources of error in addition to multiple sources of uncertainty.

---

[94] *Id.* at 3-12 & n.10.

[95] Exhibit 4 at 22 (EPA Guidance); *see also* Exhibit 5 at 7 (G. Miller, "Review of Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis by Ramboll U.S. Consulting, Inc." (Mar. 4, 2022)) (Miller 2022) (listing other sources of uncertainty in the draft mercury model).

[96] Exhibit 4 at 22 (EPA Guidance); *see also id.* at 16 ("Sensitivity analysis should be used early and often.").

[97] Exhibit 5 at 1, 10-21 (Miller 2022).

[98] *Id.* at 1.

First, the draft model significantly underestimates mercury emissions from the tailings pond, because it apparently fails to consider the cyanide in the tailings fluid.[99] This is important, because cyanide reacts with mercury, making it highly soluble in water.[100] "[T]he mercury content in tailings water is a function of cyanide content…."[101] If, as appears to be the case, the Ramboll report failed to take the cyanide into account, the estimates of mercury concentrations in the tailings pond "may be off by orders of magnitude."[102] He also compares the proposed Donlin project to the Twin Creek tailings facility, which has measured mercury emissions of 63 kg/year, far greater than the 7.5 kg/year Ramboll predicts for Donlin. Miller concludes, "Ultimately, the combination of a much higher mercury content in tailings from the Donlin Mine and the larger tailings surface area suggest that the mercury volatilization from the tailings is dramatically underestimated."[103] The underestimate of emissions from tailings is critical, because the tailings storage facility is the biggest source of nonthermal mercury emissions from the proposed mine.[104]

Second, the draft model also significantly underestimates mercury emissions from thermal sources at the mine by assuming an implausibly high 99.8% efficiency in capturing mercury.[105] Miller compares the proposed Donlin mine to the Barrick Goldstrike Mine in Nevada, which is the largest producer of byproduct mercury in that state (possibly the nation) and is doing a good job of capturing mercury.[106] While Goldstrike emits 60 pounds (27 kg) of mercury per year from the autoclaved ore based on actual measurements, the Ramboll draft mercury model predicts only 35 pounds (16 kg) from Donlin. Miller concludes that "the Donlin Mine is likely to emit at least 60 lbs of mercury, and perhaps more, since 30% more ore is being subjected to the autoclave based process."[107] Miller attributes the underestimate in part to the fact that the Ramboll draft model relies on emission factor estimates from the companies making the control equipment rather than on actual emissions from operating mines like Goldstrike.[108] Ramboll also assumes predictable levels of mercury management over time, failing to take into account the high variability of mercury managed each year in the real world. For example, at the Goldstrike Mine, annual mercury management varied by a factor of three over just five years.[109] Miller notes that the Ramboll draft model, if correct, would make Donlin

---

[99] *Id.* at 1-5.
[100] *Id.* at 2.
[101] *Id.* at 3.
[102] *Id.* at 4.
[103] *Id.*
[104] *Id.* at 2; *see also* Ramboll 2021 at ES-2, Tbl. ES-1 (listing sources of mercury emissions).
[105] Exhibit 5 at 5-7 (Miller 2022).
[106] *Id.* at 5, 6.
[107] *Id.* at 7.
[108] *Id.* at 6, 7.
[109] *Id.* at 6.

the best performing gold mine in North America despite managing and producing more mercury than any gold mine but one. This, he finds, "strains credibility."[110]

Miller concludes, "Both the fugitive emissions from the tailings facility and the emissions from the thermal sources appear to be substantially underestimated, and the resulting receiving waters are likely to have greater concentrations during and after the Donlin Mine is closed."[111] Therefore, it is not possible to find reasonable assurance that the proposed mine will comply with the chronic criterion for mercury. Donlin has failed to carry its burden of demonstrating reasonable assurance of compliance.

Dr. Miller's report is attached to this letter as Exhibit 5. ONC incorporates it by reference and requests that the Department provide a complete response to it as if set out here in its entirety.

F. Donlin must comply with both standards, which is even less likely than complying with either standard separately.

Even if it were possible to show reasonable assurance of compliance with either the temperature standard or the mercury standard, Donlin must demonstrate compliance with both (as well as every other applicable standard), which is even less likely. The applicable rule requires a single finding for all water quality standards.[112] It is roughly like needing to get heads twice in a row in a coin toss. There is a 50% chance of getting heads on either toss, but only a 25% chance of doing so on both tosses. The four equally likely outcomes are HH, HT, TH, and TT. Only the first meets the requirement.

The likelihood of meeting both standards would be low even if the odds of meeting each standard were greater than 50%. Assume, for purposes of argument, that the likelihood of meeting each standard was 70%, which would be highly optimistic based on the draft models' projections and inherent uncertainties. In that scenario, assuming the mine's impacts to temperature and mercury are independent, the odds of meeting both standards would be only 49% (70% x 70% = 49%). Thus, even with unrealistically high expectations for each standard, the odds of complying with both are less than 50% and even farther below "reasonable assurance."

The likelihood of complying with both standards in this scenario would probably be even lower than 49%, because one important input—streamflow—is not independent. It has opposite impacts on mercury and temperature. The temperature standard is most likely to be violated when streamflows are low, while the mercury standard is most likely to be violated

---

[110] *Id.* at 7.
[111] *Id.* at 8.
[112] 40 C.F.R. § 121.2(a)(3) (2019).

when streamflows are high. Thus, as streamflow conditions favor compliance with one standard, they put the other at greater risk, making it even harder to comply with both.

For these reasons, to find reasonable assurance of compliance with both the mercury and temperature standards would require wildly optimistic projections about compliance with each standard, far beyond what Donlin's draft reports justify. Donlin has failed to carry its burden of demonstrating compliance with all applicable standards.

III. Conclusion.

Donlin's draft models make it clearer than ever that there is no reasonable assurance the mine as proposed will comply with the mercury or temperature standards. Donlin commissioned these reports hurriedly, in response to ONC's appeal to Superior Court. Despite the strong incentive to demonstrate compliance with the applicable standards, the models generate outcomes that would only barely do so. Even on the face of the models, assuming for purposes of argument they were well done, these outcomes are so close to the standard and so high in uncertainty that there is no reasonable assurance of compliance with either standard, never mind both. When the assumptions, biases, omissions, and errors of the models are considered, together with the need to meet both standards at all times, it is even more clear that there is no reasonable assurance of compliance. Donlin has fallen far short of carrying its burden to demonstrate reasonable assurance of compliance with all of Alaska's water quality standards.

For thousands of years, the Yup'ik, Cup'ik, and Athabascan peoples of southwest Alaska have relied on the Kuskokwim River, the Yukon River, and their tributaries for the wealth of fish they sustain, for sustenance and health, for travel and trade, and for a way of life. The proposed mine places all of this at risk. The tribes will have to live with the consequences forever, long after Donlin has left. The Department's decision, in short, will resonate for all time. Donlin's draft reports, far from demonstrating compliance with water quality standards, merely reinforce the conclusion that there is no reasonable assurance of compliance.

For these reasons, the Department should rescind the Certificate of Reasonable Assurance.

Thank you for your careful attention to these comments.

Sincerely,

Thomas S. Waldo
Attorney for Orutsararmiut Native Council

APPENDIX A

The Ramboll draft mercury model includes individual estimates of mercury emissions from each of the following sources:

- Fugitive gaseous emissions from the:
  - tailings pond;
  - tailings beach;
  - ore stockpiles;
  - pit; and
  - waste rock facility.

- Stack emissions from:
  - autoclave 101;
  - autoclave 201;
  - carbon regeneration kiln;
  - electrowinning cells;
  - retort;
  - induction melting furnace;
  - boilers/heaters; and
  - incinerators.

- Fugitive dust emissions from:
  - drilling;
  - blasting;
  - ore loading;
  - ore unloading;
  - waste loading;
  - waste unloading;
  - ore hauling;
  - waste hauling;
  - dozer use;
  - grader use; and
  - water truck use.

- Fugitive dust wind erosion from the:
  - tailings beach;
  - haul roads;
  - access roads;
  - waste rock facility;
  - ore stockpiles;
  - overburden stockpile;
  - crusher circuit;

- ore transfer;
- pebble crusher;
- thermal processes; and
- laboratories.

Source: Ramboll 2021 at 3-12 to 3-21.

TABLE OF EXHIBITS

Exhibit No.	Description
1	Alaska Department of Environmental Conservation (ADEC), 2022 Draft Integrated Report, Fact Sheet (Jan. 24, 2022)
2	ADEC, 2022 Draft Integrated Report, Questions and Answers
3	Association of Village Council Presidents, A Resolution Opposing the Further Development and Near Future Operation of the Donlin Creek Gold Mine, Resolution 19-09-10 (Sept. 2019) & K. Shallenberger, *AVCP delegates pass resolution against Donlin Gold Mine,* ALASKA PUBLIC MEDIA (Sept. 27, 2019)
4	Environmental Protection Agency, Guidance on the Development, Evaluation, and Application of Environmental Models (Mar. 2009), https://www.epa.gov/measurements-modeling/guidance-document-development-evaluation-and-application-environmental-models
5	G. Miller, "Review of Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis by Ramboll U.S. Consulting, Inc." (Mar. 4, 2022)
6	T. Myers, "Surface Water Temperature Effects of the Proposed Donlin Project" (Nov. 24, 2021)
7	National Water Quality Monitoring Council, Water Quality Portal, excerpt for Crooked Creek, Alaska (USGS-15304010), https://www.waterqualitydata.us/ (last accessed Jan. 31, 2022)
8	National Weather Service, Bethel Temperature Data 2000-2022, https://www.weather.gov/wrh/Climate?wfo=afg (last accessed Jan. 31, 2022)
9	U.S. Global Change Research Program, Fourth National Climate Assessment, Vol. II: Impacts, Risks, and Adaptation in the United States (Rev. Mar. 2021) (excerpts)
10	University of Alaska Fairbanks, Scenarios Network for Alaska, Community Climate Charts, Crooked Creek (Qipcarpak), Alaska, https://snap.uaf.edu/tools/community-charts (last accessed Feb. 3, 2022)

anc.law.ecf@alaska.gov

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA
THIRD JUDICIAL DISTRICT AT ANCHORAGE

Orutsararmiut Native Council, Appellant, v. Alaska Department of Environmental Conservation and Donlin Gold LLC, Appellees.	Case No. 3AN-21-06502 CI

MOTION FOR INTERLOCUTORY REMAND

The Alaska Department of Environmental Conservation (ADEC or Commissioner) moves for an interlocutory remand of this appeal back to the Commissioner. Donlin Gold, LLC (Donlin) recently submitted updated scientific information and analysis to ADEC and Orutsararmiut Native Council (ONC). In the Commissioner's judgment, this information potentially affects the May 27, 2021 Order upholding the Division of Water's (Division) 2019 Certificate of Reasonable Assurance (2019 Certificate). The Commissioner respectfully asks this Court to remand ONC's appeal to him so the Department can solicit input from the parties about whether, and to what extent, Donlin's technical evaluations of mercury and water temperature affect the Commissioner's May 27, 2021 Order. Such a remand would prejudice no party and would save the parties and this Court from potentially wasting effort on an appeal resting on a set of facts that could be inaccurate or incomplete.

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

BACKGROUND

On August 10, 2018, the Division issued a Certificate of Reasonable Assurance (2018 Certificate) attesting that Donlin's proposed gold mine 10 miles north of the village of Crooked Creek, Alaska, would comply with state water quality standards implemented by ADEC. *See* Administrative Record (AR) 4643-47. ONC administratively appealed the 2018 Certificate and, after remand, the Division issued a revised Certificate of Reasonable Assurance on April 5, 2019 (2019 Certificate). AR 809-16. ONC sought informal review of the 2019 Certificate and, again after remand, the Division reissued the certificate on May 7, 2020. AR 4384. The 2020 Certificate was administratively appealed. The parties participated in a hearing via briefing to the Office of Administrative Hearings. On May 27, 2021 ADEC Commissioner Jason Brune issued a 48-page decision upholding the Division's issuance of the Certificate for the Donlin gold mine. AR 30770. The Commissioner agreed with the Division's finding that there was reasonable assurance that the mine would not violate applicable water quality standards, including protection of existing uses, and water quality standards related to mercury and temperature.

Pursuant to Alaska R. App. P. 602, ONC appealed the Commissioner's Order on June 28, 2021. On September 27, 2021, Donlin requested a temporary stay in briefing before this Court to allow Donlin to provide all parties additional information on two water quality standards at issue in ONC's appeal: mercury and temperature limits. Donlin also proposed a schedule pursuant to which the Commissioner would review the new information and report back with a proposed course of action if the new

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

information could affect the decision on appeal. The Department, recognizing the potential significance of the new analysis and information, filed a nonopposition to Donlin's request for stay on September 30, 2021. The State received Donlin's reports on October 22, and ONC received the information on October 25.

ADEC has now performed a preliminary review of the new information included in two reports provided by Donlin regarding mercury and temperature standards, and believes that the new information does indeed potentially affect the decision here on appeal. Accordingly, the Commissioner now asks this Court to exercise its authority to grant a limited interlocutory remand and enter an order instructing the parties to evaluate the information, in consultation with experts if necessary, and brief the Commissioner pursuant to the proposed procedure set forth below.

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

ARGUMENT

I. RULE OF APPELLATE PROCEDURE 520(C) GRANTS THIS COURT DISCRETION TO REMAND APPEALS TO THE AGENCY TO CONSIDER NEW INFORMATION.

Pursuant to Part Six of the Rules of Appellate Procedure, this Court functions as the appellate court for decisions rendered by an administrative agency, including ADEC. Alaska R. App. P. 601(a). This Court, pursuant to Rule 520(c), may therefore "remand the cause and direct the entry of such appropriate judgment, decree or order" or, similarly, it may "require such further proceedings to be had as may be just under the circumstances." Alaska R. App. P. 520(c). Under either clause of Rule 520(c), this Court has significant discretion to avail itself of procedures to clarify questions arising out of the administrative record. *See, e.g.*, *Seybart v. Cominco Alaska Expl.*, 182 P.3d

1079, 1098-99 (Alaska 2008) (relying in part on Rule 520(c) to affirm a superior court's decision to stay and remand "during the course of an appeal to the superior court" for supplemental proceedings).

This is particularly true when "specified questions within the special expertise or authority of an administrative agency" can be resolved with further agency proceedings. *Wade Oilfield Serv. Co. v. Providence Washington Ins. Co. of Alaska*, 759 P.2d 1302, 1305 (Alaska 1988). When, as here, technical information arises during the appeal that falls within the technical expertise of an agency, courts often remand to the agency to develop and consider that information. *See e.g.*, *Tulkisarmute Native Cmty. Council v. Heinze*, 898 P.2d 935, 939 (Alaska 1995). In *Tulkisarmute*, the Appellants sought to augment the administrative record with two reports to show "that there was insufficient data to conclude that there would be no harm to fish, and that in at least some streams degradation of fish habitat was certain to occur." *Id.* Following a hearing, the Court remanded the appeal to the Alaska Department of Natural Resources to "decide whether to accept and consider the additional materials offered by [Appellants]." *Id.* Ultimately, DNR added new documents to the record but did not amend its decision; the Appellants were still able to seek review in Superior Court. *Id.*

ADEC proposes a similar process here. Donlin's supplemental mercury modeling and temperature analysis and the potential impacts of that science on fish habitat and populations are directly analogous to the materials considered on remand in *Tulkisarmute*. *Id.* Donlin's new mercury modeling appears to incorporate new studies published since the Final Environmental Impact Statement was issued and offers

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

corrections to methodological assumptions that may affect the Commissioner's May 27, 2021 Decision. Similarly, Donlin's analysis of stream temperature in Crooked Creek appears more focused than the analysis in the FEIS and could also affect critical conclusions proffered by ONC to this Court. Both reports could therefore impact the Commissioner's ultimate decision or, at a minimum, the basis of that decision. That could alter the issues on appeal and the positions of the Parties.

Even absent technical and complex facts and analysis such as those at issue in this case and *Tulkisarmute*, courts routinely remand discrete issues to agencies while retaining jurisdiction over the appeal. *See Jeffries v. Glacier State Tel. Co.*, 604 P.2d 4, 6-8 (Alaska 1979) (discussion superior court order remanding matter to the Public Utilities Commission but retaining jurisdiction over the appeal); *City & Borough of Juneau v. Thibodeau*, 595 P.2d 626, 627 (Alaska 1979) (discussing remand for development of administrative agency record); *Voices of the Wetlands v. State Water Resources Control Bd.*, 257 P.3d 81, 97-98 (Cal. 2011) (approving of interlocutory remand to state agency for consideration of additional evidence in an environmental permitting case); *Keeler v. Superior Ct. of Cal. In & For Sacramento Cty.*, 297 P.2d 967, 970 (Cal. 1956) (approving of court remanding appeal from administrative decision to the agency for additional development). An interlocutory remand would preserve the posture of the appeal such that ONC may subsequently return to this Court, preserving ONC's rights to appellate review. The 2020 Certificate would remain in effect pending remand. And no prejudice to any party would result from delay, given that no development is yet occurring on the project.

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

II. INTERLOCUTORY REMAND SERVES THE INTEREST OF JUDICIAL ECONOMY.

An interlocutory remand would afford the parties the opportunity to crystalize the issues on appeal without wasting judicial resources on a record that is potentially incomplete or even in some ways inaccurate. The Commissioner may, upon further consideration and review of Donlin's new information on remand, issue a new decision to give effect to ADEC's program and policy. *See* AS 46.03.010; 46.03.020(2). The decision before this Court could change, slightly or significantly, with the new information and the parties' arguments about that information taken into account. Thus, it makes good sense to remand the matter to the Commissioner for further development in light of the new information before the parties and this Court devote significant resources to a decision on an outdated record.

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

CONCLUSION

The Commissioner, therefore, asks this court to STAY this appeal and remand it to ADEC with an order establishing the following process upon remand:

1. From the date of remand to the Commissioner, the parties (the Division, Donlin, and ONC) have 90 days to review Donlin's additional reports, with potential input from experts if the parties so choose.
2. From the completion of the 90 day review period, the parties have 30 days to submit simultaneous briefs to the Commissioner regarding the effect, if any, of the information provided by Donlin on the Commissioner's May 27, 2021 Decision.

3. Upon receipt of the Parties' briefs, the Commissioner has 45 days to issue a Proposed Decision.
4. The Parties then have 21 days to respond to the Proposed Decision.
5. The Commissioner then has 21 days to issue a Final Decision.
6. The parties then have 30 days to move this Court for a lift of the stay and any necessary revision to the points on appeal, or for dismissal of the appeal.

DATED November 19, 2021.

TREG R. TAYLOR
ATTORNEY GENERAL

By: /s/ *Katherine Demarest*
Katherine Demarest
Assistant Attorney General
Alaska Bar No. 1011074

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

anc.law.ecf@alaska.gov

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA
THIRD JUDICIAL DISTRICT AT ANCHORAGE

Orutsararmiut Native Council, Appellant, v. Alaska Department of Environmental Conservation and Donlin Gold LLC, Appellees.	Case No. 3AN-21-06502 CI

PROPOSED ORDER GRANTING INTERLOCUTORY REMAND

The Court, having considered the Alaska Department of Environmental Conservation (ADEC or Commissioner)'s Motion for Interlocutory Remand and the parties' responses thereto, hereby GRANTS the motion. This appeal is hereby STAYED and REMANDED to the Commissioner of ADEC with the following procedures to apply on remand:

1. From the date of remand to the Commissioner, the parties (the Division, Donlin, and ONC) have 90 days to review Donlin's additional reports, with potential input from experts if the parties so choose.
2. From the completion of the 90 day review period, the parties have 30 days to submit simultaneous briefs to the Commissioner regarding the effect, if any, of the information provided by Donlin on the Commissioner's May 27, 2021 Decision.

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

3. Upon receipt of the Parties' briefs, the Commissioner has 45 days to issue a Proposed Decision.
4. The Parties then have 21 days to respond to the Proposed Decision.
5. The Commissioner then has 21 days to issue a Final Decision.
6. The parties then have 30 days to move this Court for a lift of the stay and any necessary revision to the points on appeal, or for dismissal of the appeal.

DATED: ____________________, 2021.

____
The Honorable Catherine Easter
Superior Court Judge

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

anc.law.ecf@alaska.gov

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA
THIRD JUDICIAL DISTRICT AT ANCHORAGE

Orutsararmiut Native Council, Appellant, v. Alaska Department of Environmental Conservation and Donlin Gold LLC, Appellee.	Case No. 3AN-21-06502 CI

CERTIFICATE OF SERVICE

I certify that on November 19, 2021, a true and correct copies of the Motion for Interlocutory Remand, Proposed Order Granting Interlocutory Remand, and this Certificate of Service were served on the following via email:

Thomas S. Waldo
Olivia Glasscock
Maile Tavepholjalern
EARTHJUSTICE
Email: tom.waldo@earthjustice.org
Email: oglasscock@earthjustice.org
Email: mtave@earthjustice.org

Eric B. Fjelstad
James N. Leik
Cameron Jimmo
PERKINS COIE LLP
Email: EFjelstad@perkinscoie.com
Email: JLeik@perkinscoie.com
Email: CJimmo@perkinscoie.com
Email: docketANC@perkinscoie.com

/s/ Angela Hobbs
Angela Hobbs
Law Office Assistant

DEPARTMENT OF LAW
OFFICE OF THE ATTORNEY GENERAL
ANCHORAGE BRANCH
1031 W. FOURTH AVENUE, SUITE 200
ANCHORAGE, ALASKA 99501
PHONE (907) 269-5100

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA
THIRD JUDICIAL DISTRICT AT ANCHORAGE

ORUTSARARMIUT NATIVE COUNCIL, *Appellant,* v. ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION and DONLIN GOLD LLC, *Appellee.*	Case No. 3AN-21-06502CI

ORDER GRANTING INTERLOCUTORY REMAND

After considering the Alaska Department of Environmental Conservation's (the Department) motion for interlocutory remand in the above captioned matter, and the parties' responses thereto, the court adopts the appellant's proposed order GRANTING the motion in part, with modifications to procedure number 5, as stated below. This appeal is hereby STAYED and REMANDED to the Department with the following procedures to apply on remand:

1. From the date of remand to the Department, Appellant Orutsararmiut Native Council (ONC) shall have 90 days to submit comments to the Division of Water (the Division).
2. The Division shall have 45 days following service of ONC's comments to issue a decision whether to uphold, modify, or rescind the Certificate of Reasonable Assurance.
3. ONC or Donlin Gold LLC (Donlin Gold) may seek adjudication of the Division's decision under 18 AAC 15.200. Any adjudication shall follow the procedures specified in applicable statutes and regulations.
4. Following a final decision from the Department, the parties shall have 30 days to move this court for a lift of the stay and any necessary revision to the points on appeal, or for dismissal of the appeal.

5. Pursuant to the applicable statutes, regulations, and Rules of Appellate Procedure, the Department shall serve the parties to this action and appeal with its final decision and any other relevant or required records in this matter for purposes of adjudication and/or appeal.
6. The scope of the remand is limited to the questions of compliance with standards for mercury and stream temperature.

IT IS SO ORDERED.

DATED at Anchorage, Alaska this 29th day of December, 2021.

Catherine M. Easter

CATHERINE M. EASTER
Superior Court Judge

I certify that on 12/29/21
a copy of the above was mailed to:

Katherine Demarest
Eric B. Fjelstad
James N. Leik
Cameron Jimmo
Thomas S. Waldo
Olivia Glasscock
Maile Tavepholjalern

Lynn Perez, Judicial Assistant

Prepared for:

Donlin Gold, LLC
Anchorage, Alaska

Prepared by:

Ramboll US Consulting, Inc.
7250 Redwood Blvd., Suite 105
Novato, California 94945

October 22, 2021
1690022020

Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis

Bright ideas. Sustainable change.

Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis

Ramboll
7250 Redwood Boulevard
Suite 105
Novato, CA 94945
USA

T +1 415 899 0700
https://ramboll.com

CONTENTS

Appendix

Table of Figures

Table of Tables

EXECUTIVE SUMMARY

Ramboll was retained by Donlin Gold LLC (Donlin Gold) to complete a mercury study that builds upon previous studies supporting the Final Environmental Impact Statement (FEIS) for the proposed Donlin Gold project (Project) (United States Army Corps of Engineers (USACE) 2018). The purpose of this study is to provide a more refined estimate of the Donlin Gold mine's potential impacts on mercury concentrations in the surface water of nearby streams.

The FEIS reported that the atmospheric deposition of total mercury in the vicinity of the Project could increase by approximately 40% due to the Project and that this could lead to a corresponding 40% increase in total mercury concentrations in surface water near the Project. (USACE 2018). This was a conservative assessment in three principal respects. First, the Project's mercury emissions and, in turn, the corresponding deposition, associated with the Project were overestimated. Second, the assumption that the percentage increase in atmospheric deposition resulting from the Project would translate into an equivalent increase in surface water mercury concentrations made no accounting for the well-recognized and significant attenuation (estimated to be at least 93%) associated with mercury sequestration in soils and uptake in vegetation. Third, it assumed all baseline mercury in the surface water was the result of atmospheric deposition, and made no accounting of geologic contributions originating from erosion of mercury-bearing rock, which is the source of the majority of mercury loading into the surface water.

The current study applies a more refined methodology, incorporates new studies published since the FEIS was issued, and uses additional information and data that more accurately reflect site conditions, to calculate a more accurate estimate of the potential total mercury concentrations in the Crooked Creek watershed resulting from the Project. The current analysis supplements the previous FEIS analysis in the following ways:

- A mass balance approach was used to estimate the effect of mercury deposition on concentrations in streams. This approach accounts for the fact that current mercury concentrations in the streams near the mine site are due to both atmospheric deposition and geologic sources from weathering and erosion of mercury-enriched surface and subsurface geologic features. The contribution of geologic mercury is characterized using new sampling data. The approach also accounts for the significant retention of mercury in the terrestrial environment.
- The current analysis provides a more accurate accounting of mercury emissions and corresponding deposition from the Project using data and methods that are more representative of the Project.
- The current analysis accounts for stream diversion and runoff management and treatment during the Project that will reduce streamflows and mercury mass loading to Crooked Creek due to management of flows from the American and Anaconda creek watersheds.

The updated mercury emissions are presented in Table ES-1. Atmospheric inorganic mercury emitted by the Project exists in three forms: gaseous elemental mercury (Hg(0)), gaseous divalent or oxidized mercury (Hg(II)), and particulate divalent mercury (Hg(P)). The updated emissions from stacks at the processing facility are 72% lower than estimated in the FEIS. Similarly, estimated fugitive gaseous emissions from the Tailings Storage Facility (TSF) are 73% lower than estimated in the FEIS. Other fugitive gaseous emissions (from the ore stockpiles, open pit, and waste rock facility) are comparable to the FEIS estimates. Fugitive dust (particulate) mercury emissions are estimated to be higher than in the FEIS by about 61%. The reasons for all of the above differences are outlined in Section 3.2. Mercury emissions from boilers, heaters, and incinerators at the Project which are relatively small and were not previously modeled in the FEIS are also now included in the modeling. In sum, the total Project mercury emissions are estimated to be 30.0 kilograms per year (kg/yr).

Table ES-1. Modeled annual mercury emissions from Donlin Gold mine sources.

Emissions Source	FEIS (kg/yr)				Updated Values (kg/yr)			
	Hg(0)	Hg(II)	Hg(p)	Total Hg	Hg(0)	Hg(II)	Hg(p)	Total Hg
Processing Facility	56.2	0.8	0.9	57.9	14.7	0.4	0.9	16.0
Fugitive: Tailings Gaseous	27.8			27.8	7.5			7.5
Fugitive: Other Gaseous	1.8			1.8	1.7			1.7
Fugitive Dust			1.8	1.8			2.9	2.9
Boilers, heaters, incinerators*	-	-	-	-	1.0	0.6	0.4	2.0
Total	85.8	0.8	2.7	89.3	24.9	1.0	4.1	30.0

Numbers may not add exactly due to rounding.

* Not considered in mercury modeling in FEIS

Atmospheric mercury deposition in the watershed was modeled using the same air deposition model as applied for the FEIS with these updated emissions and other updates to deposition modeling parameters.

The degree to which changes in atmospheric mercury flux is retained by soil within a watershed, and thus not transported by runoff into surface waters, is characterized by the mercury retention rate. Once deposited to a watershed, most mercury is rendered immobile by sorption to organic matter in soils (Figure ES-1). Mercury not transported through the watershed and into the receiving water is thus considered to be "retained" within the watershed. The ratio of mercury retained to mercury deposited is called "mercury retention." Using sediment mercury accumulation data from environmentally similar watersheds (based on topography, plant community, and land use), the Crooked Creek watershed mercury retention rate was determined to be 93% or higher. This retention fraction was used in subsequent mass loading calculations to estimate mercury loading to streams in the Project area from atmospheric and geologic sources. The mass loading analysis concluded that almost all the mercury mass loading in streams is from geologic sources.

To corroborate the mass loading analysis, a geochemical fingerprinting method was used to evaluate the relative contributions of atmospheric and geological mercury to soils, sediments, and suspended particulates. As bedrock weathers and erodes, it supplies solid material found in soils and sediments throughout a watershed (Figure ES-1). This material includes naturally occurring geologic mercury, as well as other geologic metals. The ratio of mercury to a geologic tracer element (aluminum in this study) in the bedrock acts as a geologic signature. The ratio of mercury to the tracer metal is then measured in surface materials exposed to atmospheric deposition (that is, soil, sediment, and suspended particulates in the water column; Figure ES-1) and compared to the bedrock ratio. Where the ratio is greater in the surface material than in the bedrock, the excess mercury is attributable to atmospheric sources (Hissler and Probst 2006; Guédron et al. 2013).

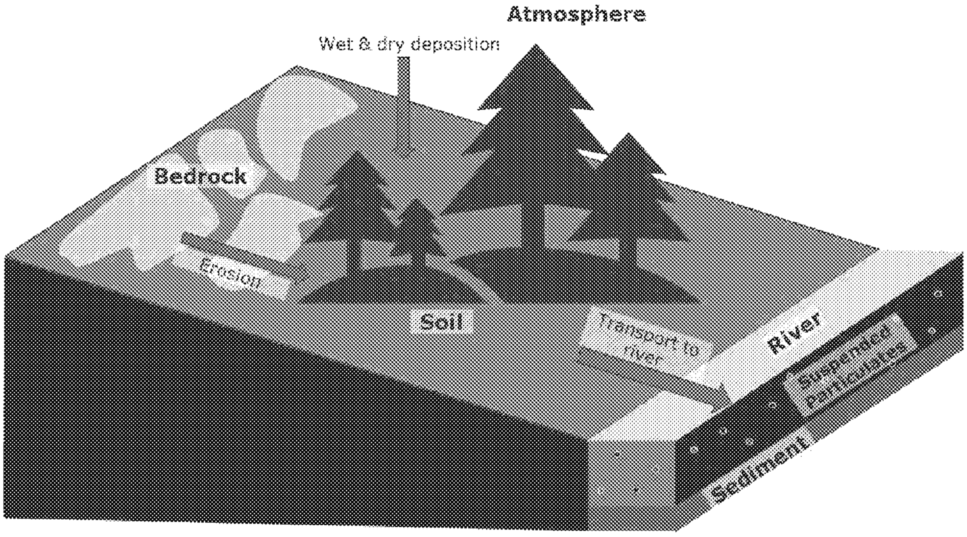


Figure ES-1. Schematic showing mercury sources, transport mechanisms, and storage compartments within the watershed.

Waste rock data collected from the mine site (SRK 2011) was used to determine the mercury and aluminum concentrations in local bedrock. Samples of soil, sediment, and suspended particulates were collected during the Donlin Gold 2021 summer sampling program (Arcadis 2021) and analyzed for mercury and aluminum. The mercury to aluminum ratios in the soils, sediments, and suspended particulates were within the range of the waste rock ratio values. This indicates that the proportion of atmospheric mercury in soils, sediments, and suspended solids is extremely small relative to geologic sources. The empirical evidence for a very small contribution of atmospheric mercury supports the findings in the mercury mass balance discussed below.

A detailed mercury mass balance analysis was conducted at five monitoring stations (DCBO on Donlin Creek, AMER on American Creek, ANDA on Anaconda Creek, CCAC on the main stem of Crooked Creek, and CCAK[1] on Crooked Creek near the confluence with the Kuskokwim River) and their associated drainage areas (see Figure ES-2). These stations were selected because they had sufficient historical concurrent water quality (mercury concentrations) and streamflow data (from 2007-2021). The mass balance analysis quantifies the long-term average rates of mercury entering the watersheds from geologic and atmospheric sources and mercury leaving the watersheds as streamflow. Quantifying the two sources of baseline loadings is necessary for predicting the impact of Project activities on downstream water quality. The mass balances for ANDA and AMER characterize mercury transport within watersheds where future Project activities will take place. The mass balances for CCAC and CCAK illustrate the combined effects of mercury mass loading from multiple upstream watersheds to the lower reaches of Crooked Creek.

[1] CCAK is near the CR0.3 station.

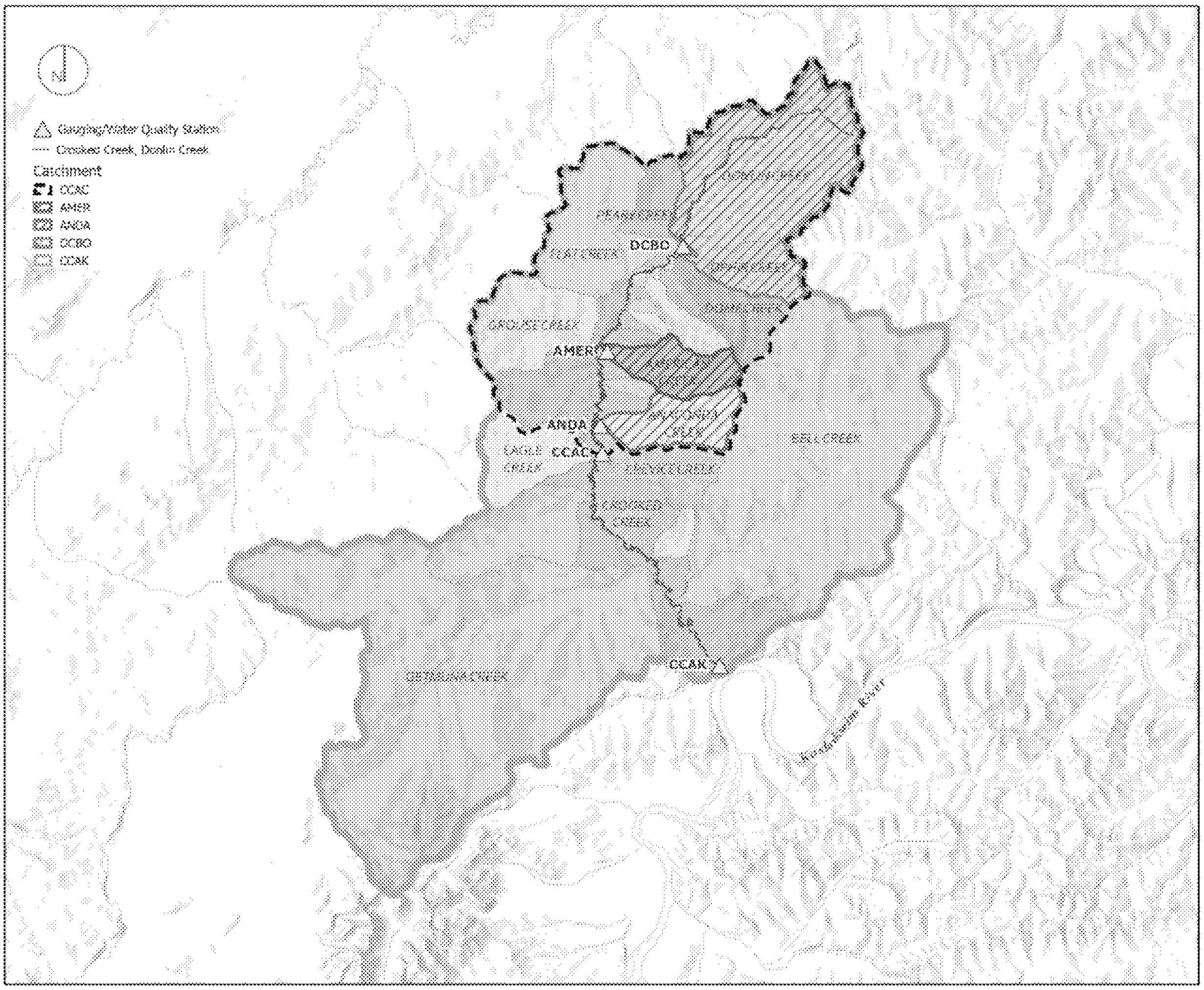


Figure ES-2. Monitoring stations and watersheds considered in the mercury mass balance analysis.

The results of the mass balance analysis under baseline conditions are shown in Table ES-2. The total loading is the long-term average mercury mass loading over 2007-2021 measured at each station. The primary sources of mercury in surface water in the Crooked Creek watershed are either geologic (i.e., originating from erosion of mercury-bearing rock) or atmospheric (i.e., originating from background deposition of atmospheric mercury). Thus, the mass balance calculation for a given watershed balances the amount of mercury in surface water exiting from the watershed (i.e., mercury mass loading at the drainage point) with the amount of mercury entering surface water (i.e., sum of geologic and non-retained atmospheric loading).

Table ES-2. Baseline mercury mass balance.

Station	Drainage Area (km^2)	Geologic Loading (kg/yr, % of total)	Background Atmospheric Loading (kg/yr, % of total)	Total Baseline Mercury Mass Loading (kg/yr)
DCBO	92.1	0.134 (71%)	0.054 (29%)	0.188
AMER	17.75	0.064 (86%)	0.010 (14%)	0.074
ANDA	20.3	0.093 (89%)	0.012 (11%)	0.105
CCAC	292	0.535 (76%)	0.172 (24%)	0.707
CCAK	869	3.32 (87%)	0.511 (13%)	3.83

Numbers may not add exactly due to rounding

Table ES-3 presents mercury mass balances for individual stations under Project conditions. Surface runoff will be managed and treated at several areas during the Project (Donlin Gold Water Resources Management Plan, SRK 2017). These areas include almost all the American Creek watershed, the TSF area within the Anaconda Creek watershed, and some smaller areas such as the South Overburden Stockpile. The estimated values shown incorporate Project-related mercury emissions, implementation of surface water runoff management, and discharges of treated water containing trace levels of mercury in the Wastewater Treatment Plant (WTP) outfall. The values shown for background atmospheric loading reflect the reduction due to runoff management. The mass balance for CCAC incorporates the effect of reduced loading in the American Creek and Anaconda Creek watersheds. That reduction is more than the predicted increase in project-related deposition across the drainage area. The same is also true at CCAK, which represents the entire Crooked Creek watershed. In summary, the mercury study indicates that the Project would likely result in negligible impacts (<1%) on mercury mass loading in streams near the Project area and, in most cases, result in reductions from baseline mercury mass loadings.

Table ES-3. Project conditions mercury mass balance.

Station	Runoff Management (km^2, % of Drainage Area)	Mercury Mass Loading During Project (kg/y)					%Change in Total Loading from Baseline
		Geologic	Atmospheric (Background)	Atmospheric (Project)	WTP Outfall	Total	
DCBO	0 (0%)	0.134	0.054	0.0015	-	0.190	0.8%
AMER	17.69 (99.7%)	0.00020	0.00003	0.00017	-	0.00040	-99.5%
ANDA	10.5 (52%)	0.045	0.0057	0.0029	-	0.054	-49.0%
CCAC	32 (11%)	0.477	0.153	0.030	0.033	0.693	-2.0%
CCAK	32 (3.7%)	3.20	0.492	0.046	0.033	3.77	-1.6%

Numbers may not add exactly due to rounding.

As shown in Table ES-3, the long-term average mercury mass loading at five stations within the Crooked Creek watershed was estimated to stay essentially the same or decrease due to Project activities. As mercury mass loading is the product of flow and mercury concentration, a reduction in average loading from baseline conditions will also result in a reduction in mercury concentrations, assuming that streamflow is unaffected by the Project. However, where the surface water flow also changes due to the Project, an analysis was done to estimate the effect on stream mercury concentrations, which is how the applicable water quality standard is expressed.

As described in the FEIS, surface water flows near the Project area will be reduced due to the diversion of surface water runoff and the reduction in groundwater seepage to surface water due to pit dewatering and other water management systems such as the TSF seepage collection system. Although some of this water will be treated and discharged back to Crooked Creek, a portion of the water will be consumed as part of mine operations. The FEIS did not identify any streams in which streamflow would increase during the Project as compared to baseline conditions. To evaluate the impact of reduced streamflow on concentrations at four stations (ANDA, AMER, CCAC, and CCAK) where streamflow is predicted to decrease during the Project, the correlation between mercury concentration and streamflow under baseline conditions was evaluated. In all cases, higher flows are associated with higher mercury concentrations, and lower flows are associated with lower mercury concentrations. Although this relationship was evaluated under baseline conditions, the positive correlation would also be representative of Project conditions, since both the mass balance and geochemical fingerprinting evaluations found atmospheric deposition to be a relatively minor contribution to mercury mass loading in Crooked Creek relative to geological sources. Based on these results, the reduction in streamflow as a result of Project water use would be associated with a decrease in mercury concentrations in surface water at locations near and downstream of the Project relative to baseline conditions.

At DCBO, located on Donlin Creek upstream of the Project, streamflow is not expected to change as a result of the Project. However, the mercury mass balance under Project conditions predicts a small increase in mercury mass loading at DCBO due to Project mercury air deposition in the watershed. To quantify the impact on mercury concentrations at DCBO, the same percentage increase in mercury mass loading predicted at DCBO (0.8%) was applied to historical mercury concentrations measured at DCBO to determine the effect of this increase on the likelihood of concentrations being higher than 12 ng/L (the State of Alaska Water Quality Standard (AWQS)). After applying the assumed 0.8% concentration increase to all the baseline measurements at DCBO, there was no change in the number of samples with mercury concentrations above 12 ng/L. Thus, the Project would have a negligible impact on mercury water quality in the DCBO watershed. Similarly, negligible mercury water quality impacts would be expected in other watersheds, both within and outside the Crooked Creek watershed, where very small increases in mass loadings are predicted and the Project would not impact streamflows. This is especially the case as the distance from the Project increases and the amount of Project-related deposition is minimal.

1 INTRODUCTION

1.1 Purpose of Study

The mercury study described in this report was conducted by Ramboll US Consulting Inc. (Ramboll) for Donlin Gold LLC, Alaska. The purpose for this study is to conduct a robust mercury analysis that could help inform regulatory actions for the proposed Donlin Gold mine ("Project"). The study will further define the baseline contributors to mercury concentrations currently observed in streams in the Crooked Creek watershed near the proposed Project and estimate the change in these mercury concentrations due to the proposed Project activities. The study builds upon work previously performed for the Donlin Gold Final Environmental Impact Statement (FEIS) (USACE 2018) with updated data and methods.

1.2 Outline of Report

Chapter 2 contains background information on the Project and the Crooked Creek watershed, including an overview of the analysis previously conducted of mercury air deposition and surface water quality. Data, methods, and results from the current study are presented in Chapter 3. The implications for changes in stream water mercury concentrations due to the Project are also discussed in Chapter 3. References are provided in Chapter 4.

2 BACKGROUND INFORMATION

2.1 Overview of the Crooked Creek Watershed and Project Location

Crooked Creek is a tributary of the Kuskokwim River in southwestern Alaska. Figure 2.1-1 shows the Crooked Creek watershed boundary, which includes the main stem of Crooked Creek and its tributaries. The Crooked Creek watershed has been divided into 23 smaller watersheds draining individual reaches and tributaries. The Project facilities are mainly within the American Creek, Anaconda Creek, and Snow Gulch watersheds.

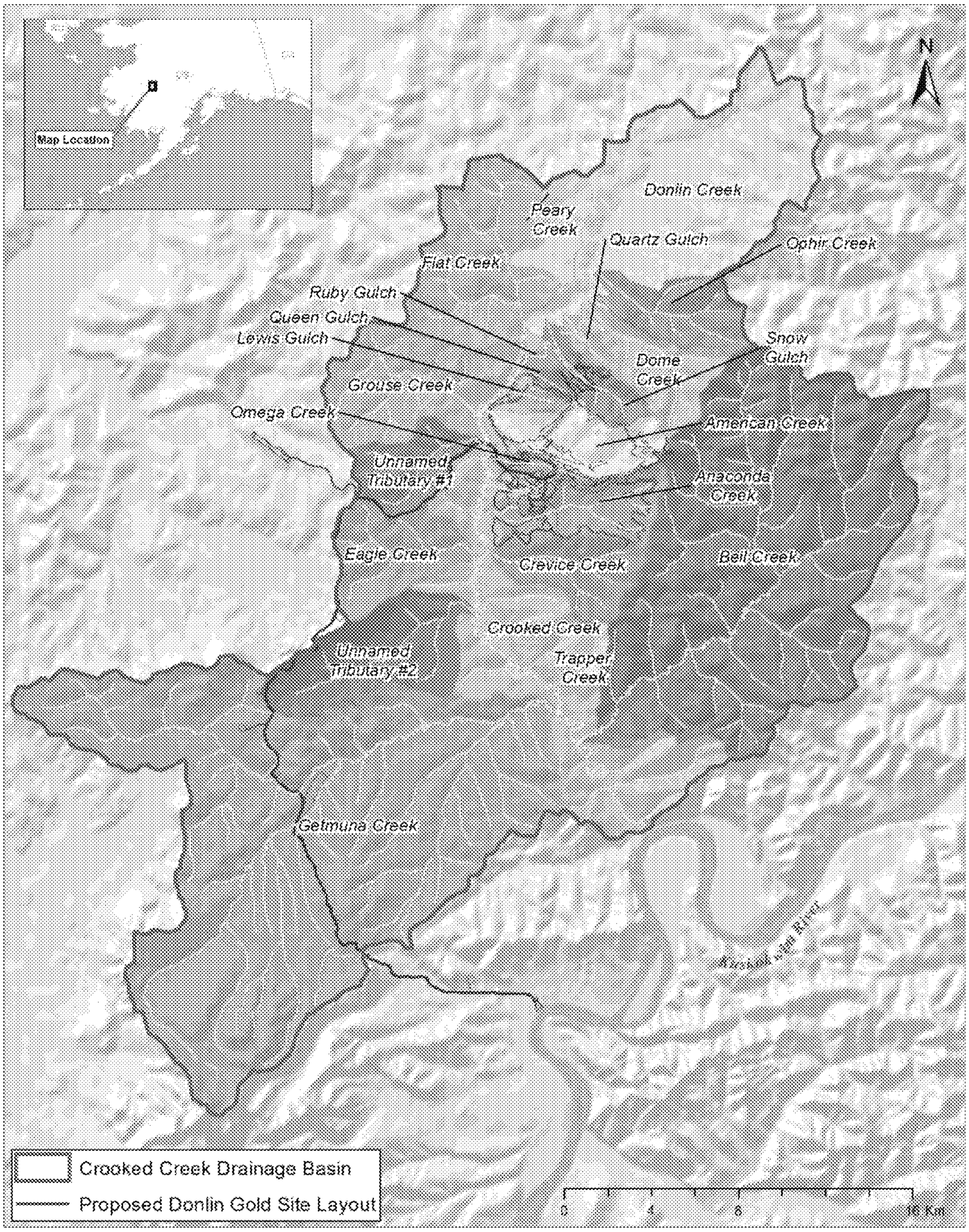


Figure 2.1-1. Crooked Creek watershed and Project location.

2.2 Key Differences between Previous Work and this Study

ENVIRON[2] (2013) estimated the baseline (i.e., current, pre-Project) annual atmospheric mercury deposition flux near the mine site to be approximately 8.4 micrograms per square meter per year ($\mu g/m^2$-yr) using a combination of mercury deposition monitoring and modeling. ENVIRON (2015) studied the potential atmospheric impacts of the Project's mercury air emissions from stack and fugitive dust sources using a conservative modeling approach. The FEIS (p. 3.7-151) estimated the average potential increase in atmospheric mercury deposition in the Crooked Creek watershed due to the Project to be conservatively 40% higher than the baseline. The analysis in the FEIS then made the conservative assumption based on Arcadis (2014) that an approximately 40% increase in mercury deposition rates could lead to a proportional 40% increase in mercury concentrations in surface water in the Crooked Creek drainage area. This assumption results in a significant overestimation of the Project's impacts because mercury loading and resultant concentrations in surface waters are, in fact, dominated by geological contributions (i.e., erosion of mercury-bearing rock) and mercury deposited via atmospheric deposition is significantly mitigated by retention or sequestration in the soils and vegetation. As explained in Chapter 3, the supplemental analysis accounts for these factors.

The analysis also updates and more accurately characterizes the Project's mercury emissions and includes an updated modeling analysis, resulting in a more accurate estimate of the Project's mercury deposition. Moreover, stream diversion and runoff management and treatment measures during the Project will reduce existing streamflows and atmospheric mercury mass loading to Crooked Creek. These phenomena are discussed and addressed in this study. In addition, a detailed analysis of mercury mass loadings to streams near the Project was developed and calibrated with site-specific monitoring data and by incorporating information from Donlin Gold on proposed runoff management and treatment measures. Table 2.2-1 provides a listing of the key differences between the FEIS mercury analysis and the current analysis.

Table 2.2-1. Overview of key differences between FEIS analysis and supplemental analysis.

	FEIS Analysis	Supplemental Analysis (Current Study)
Particulate (dust) emissions sizes	• Assumed particulate emissions are very coarse particles larger than 10 microns (PM_{10}+)	• Particulate emissions are distributed across particles smaller than 2.5 microns ($PM_{2.5}$), particles between 2.5 and 10 microns ($PM_{2.5-10}$) and particles larger than 10 microns (PM_{10}+)
Wet deposition	• Used wet deposition scavenging coefficients representative only of very coarse particles	• Used updated wet deposition scavenging coefficients that vary by particle size based on literature review
Tailings pond vapor mercury emissions	• Used estimated TSF pond mercury concentration of 0.315 mg/L	• Used pond concentration of 0.073 mg/L from 2017 Water Resources Management Plan (WRMP)

[2] ENVIRON is now part of Ramboll.

	FEIS Analysis	**Supplemental Analysis (Current Study)**
Tailings beach vapor mercury emissions	• Assumed no portion of the beach was dry (all wet) • Wet beach flux estimated from linear correlation relating mercury emission flux to mercury concentration using data from Eckley et al (2011a, 2011b)	• Divided the beach into wet (33%) and dry (67%) areas based on the rate of movement of the active beach area • Wet beach flux calculation similar to FEIS approach • Dry beach flux calculated using the Eckley (2011a, 2011b) correlations • Updated TSF surface area to include peak surface area at end of operations

Vapor mercury emissions from ore stockpiles, pit, waste rock facility	• Used mercury concentrations from block model[3] in FEIS
	  ○ Ore = 1.62 ppm
	  ○ Pit = 0.79 ppm
	  ○ Waste rock facility = 0.63 ppm
		• Used mercury concentrations from geometric mean of ore and waste rock samples
		  ○ Ore = 1.27 ppm
		  ○ Pit = 0.695 ppm
		  ○ Waste rock facility = 0.59 ppm

Mercury emissions from stacks	• Emissions data for processing facility (thermal units) from Air Sciences during Draft EIS development	• Emissions data from Air Sciences (2021) for processing facility (thermal units) and for stacks at boilers, heaters and incinerators
Mercury emissions from fugitive dust	• Used emissions averaged over mine life	• Used emissions from peak year of mine life
Mercury retention in soil	• Did not account for sequestration of mercury in soil	• Accounted for the retention of mercury in the soil based on literature review and Crooked Creek watershed parameters

[3] The block model is a geologic computer model that shows the three-dimensional location of each type of rock.

	FEIS Analysis	Supplemental Analysis (Current Study)
Mercury concentration in streams	• Assumed increase in deposition from project would result in proportional increase in stream concentrations of mercury • Did not account for beneficial effects of surface runoff management and treatment	• Distinguished geologic and atmospheric sources in baseline loading • Conducted new sampling for water/soil/ sediment • Developed flow and loading regression model to fill in gaps in existing data • Accounted for atmospheric loading reduction due to soil retention in mass balance analysis • Accounted for loading reduction due to runoff management and treatment • Accounted for changes in stream concentrations due to streamflow reductions from the Project

3 METHODS AND RESULTS

3.1 Conceptual Model

The terrestrial environment is an important link for mercury transport between the atmosphere and aquatic systems (Figure 3.1-1). Around half of all global environmental mercury (i.e., not sequestered for a long time in mineral phases) exists in soils and plants (Obrist et al. 2018). The behavior of mercury in the terrestrial environment determines the impact of atmospheric mercury deposition on aquatic systems (i.e., how changes in atmospheric mercury deposition affect how much mercury enters aquatic systems).

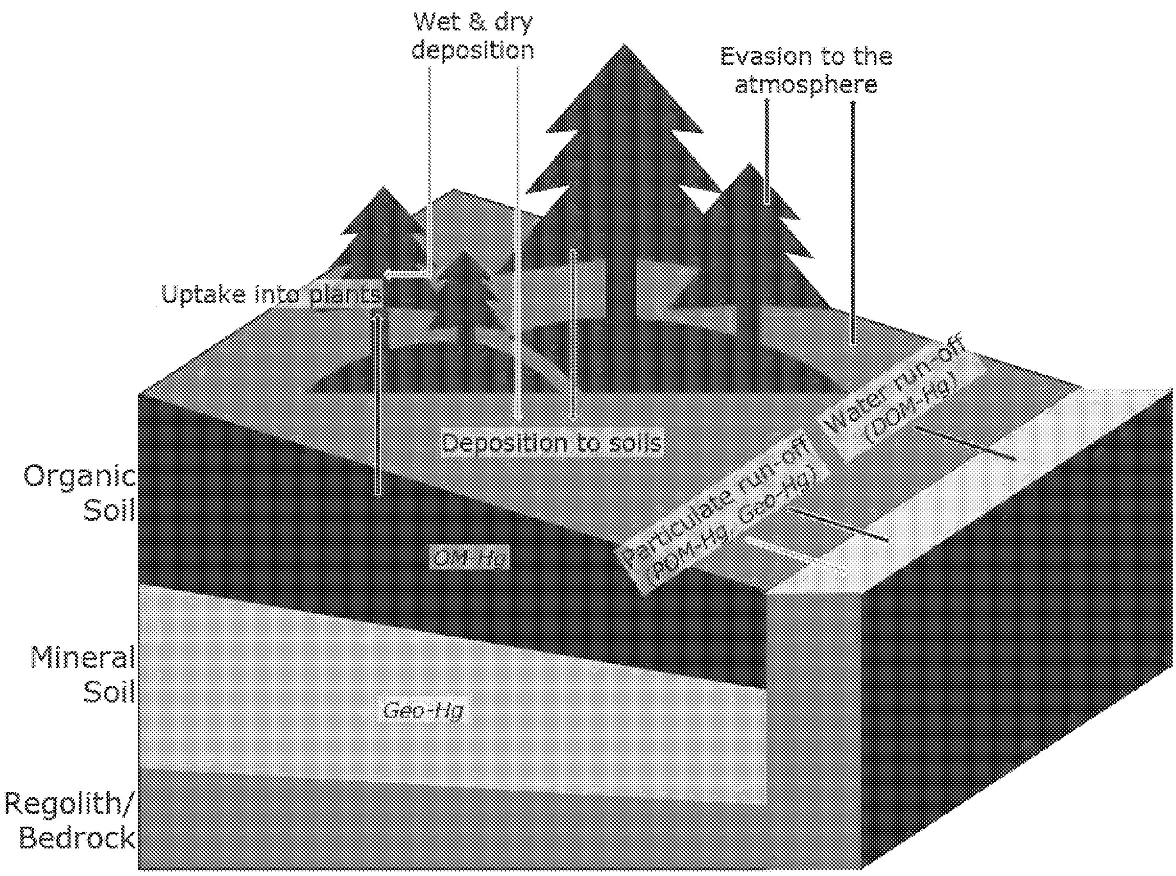


Figure 3.1-1. Mercury cycle. Phases of mercury include mercury bound to organic matter (OM-Hg), mercury bound to particulate organic matter (POM-Hg), mercury bound to dissolved organic matter (DOM-Hg), and mercury in mineral phases (Geo-Hg).

3.1.1 Terrestrial Mercury Cycle

Mercury is introduced into the terrestrial environment from two sources: atmospheric deposition and erosion of geologic materials. Atmospheric mercury is deposited onto land surfaces via wet and dry deposition as divalent or elemental mercury.[4] Additionally, mercury in soils can originate from native bedrock containing geologic mercury. As exposed bedrock weathers and erodes, the eroded material contributes to soil matter. The relative contributions of atmospheric and geologic mercury to the terrestrial environment depends on local atmospheric mercury sources and how enriched the local

[4] Divalent mercury may be gaseous or particulate, while elemental mercury is primarily gaseous.

geology is in mercury. Mercury stored in the terrestrial environment thus represents accumulation of mercury over geologic time scales derived from both atmospheric and geogenic sources (St. Louis et al. 2016). Atmospheric mercury tends to accumulate in upper soil layers, which are often rich in organic matter. Mercury in deeper, mineral soil layers has a greater contribution from geologic sources (Smith-Downey et al. 2010; Obrist et al. 2018). The relative proportion of geologic versus atmospheric mercury in soils depends on the local geology. Areas with high natural geologic concentrations of mercury, such as the Kuskokwim Mountain region (Malone 1962), will have a higher proportion of geologic mercury compared to atmospheric mercury. Upland areas[5] of watersheds frequently sequester more atmospheric mercury than they re-emit to the air (St. Louis et al. 2016), and some boreal upland areas are net sinks for mercury overall (i.e., more mercury enters the area than leaves as emissions or runoff; St. Louis et al. 1996).

Once atmospheric mercury reaches the land surface, mercury either evades to the atmosphere, is taken up into plants, sorbs to soils, or is transported to bodies of surface water. Volatilization (evasion) of mercury (i.e., the release of gaseous mercury) from the terrestrial environment occurs because elemental mercury readily evaporates at ambient temperatures. On plants or at the soil surface, deposited divalent mercury can undergo photoreduction to elemental mercury and contribute to evasion from the terrestrial environment (St. Louis et al. 2016). Globally, approximately 10% of terrestrial mercury is stored in plants and the rest is stored in soil (Selin et al. 2009). Mercury storage in plants is transitory, as this mercury is returned to the soil by litterfall (dead plant material falling to the ground). Litterfall is the dominant source of elemental mercury to boreal forest and tundra soils (Obrist et al. 2017; Jiskra et al. 2015).

In soils, mercury sorbs very strongly to organic matter. Once incorporated into the soil organic carbon pool, mercury becomes relatively immobile, and its transport is controlled by the mobility and reactivity of dissolved and particulate organic matter. Transport of mercury in soil solution occurs when dissolved organic carbon is high, with migration typically limited to less than a meter (Grigal et al. 2002). Soil mercury associated with organic carbon can be mobilized (e.g., be transported in runoff) when organic carbon is broken down (Smith-Downey et al. 2010). In boreal forests and tundra ecosystems, the average turnover rate of organic-associated mercury is on the order of 550 to 700 years (Smith-Downey et al. 2010). This process drives the high retention of mercury in Arctic watershed soils (as discussed in Section 3.1.2).

A small proportion of soil mercury (both organic and mineral) is transported to surface waterbodies by runoff and erosion. Typically, elevated fluxes of mercury and organic matter from the soil are observed during snowmelt or storm events. These events often represent a large proportion of the annual mercury transport from soils to surface water (Demers et al. 2010; Dommergue et al. 2003; Haynes and Mitchell 2012). Mercury isotope spike studies have shown that the majority of mercury transported in these runoff events is more than 99% older mercury, as opposed to mercury deposited in the previous 3 to 6 years (Harris et al. 2007; Oswald et al. 2014). Because deposited mercury is retained in the catchment area for tens to hundreds of years, the quantity of mercury transported from upland soils to surface water represents a long-term history of geologic and atmospheric mercury accumulation in the watershed rather than recent deposition trends. Therefore, short-term increases in atmospheric deposition do not cause immediate increases in mercury export from watersheds, and they contribute only a small amount to the mercury exported in any given year.

[5] Upland area is the area of a watershed that does not receive regular flooding by a stream.

3.1.2 Mercury Retention in Crooked Creek Watershed Soils

Many studies have attempted to quantify the relationship between the amount of mercury entering a watershed through atmospheric deposition versus the amount of mercury leaving the watershed through runoff. The mercury leaving the watershed (or exported) may be of either atmospheric or geologic origin. Mercury not exported is considered to be retained in the watershed. The ratio of mercury retained to atmospheric mercury deposited, is called the "mercury retention rate." Because mercury exported from the watershed may have been stored in the soils for hundreds of years (Section 3.1.1) before being mobilized, mercury retention represents the overall behavior of mercury over long timescales in the watershed. Mercury retention can be used to estimate the mercury contribution of a watershed to a body of water. In this study, the mercury retention rate is used to more accurately determine the mass balance of mercury within the Crooked Creek watershed (Section 3.3.5). This section describes the determination of a mercury retention rate for the Crooked Creek watershed.

The mercury retention rate for the Crooked Creek watershed was determined using mercury accumulation data in sediments from environmentally similar locations. The Crooked Creek watershed is remote and mountainous, and is primarily covered by evergreen forest, followed by scrub and shrub cover and deciduous forest (USACE 2018).

3.1.2.1 Mercury Retention Rate by Sediment Mercury Accumulation

Several studies (Swain et al. 1992; Kamman and Engstrom 2002; Drevnick et al. 2016) use mercury accumulation in lake sediment to calculate a mercury retention rate in a watershed. Because this method incorporates data from many similar watersheds, it determines a general mercury retention rate for an area. The rate of mercury accumulation in lake sediments (on the y axis) is plotted against the ratio of the watershed surface area to the lake surface area (on the x axis). A least squares linear regression model is then fit to the data:

$$Sediment\ Hg\ accumulation\ \left({}^{\mu g}\!/_{m^2 \cdot year}\right) = slope \times \left({}^{Watershed\ Area}\!/_{Lake\ Area}\right) + intercept$$

The intercept of the model represents the mercury accumulation rate in the lake if the watershed area was zero, meaning all mercury to the lake came from atmospheric deposition. Therefore, the intercept is equivalent to the atmospheric deposition rate per unit area. The slope of the model indicates the increase in mercury flux to the lake from each increasing unit area of the watershed, and therefore represents the mercury flux from the watershed. The ratio of the slope to the intercept thus quantifies the proportion of mercury deposited on the watershed that is transported to the lake; subtracting this ratio from 1 gives the proportion of mercury retained in the watershed:

$$1 - \frac{slope}{intercept} = Proportion\ Hg\ retained\ in\ watershed$$

Although this method uses lake data to derive a retention value, the proportion of mercury retained in the upland watershed area applies to river watersheds as well. The model assumes that the amount of mercury accumulation in sediment reflects the deposition of mercury at the water surface. Due to the dynamic nature of rivers, sediment accumulation in rivers does not meet this assumption. However, there is no fundamental difference between river and lake watersheds. In a single large watershed, rivers may flow into a lake, or a lake may discharge into a river. What this model determines is the mercury retention rate in watersheds with common geologic and ecological features, and that rate would apply regardless of the type of receiving water body in the watershed.

3.1.2.2 Mercury Retention Rate Determination

Drevnick et al. (2016) compiled an extensive data set of sediment mercury accumulation rates, watershed areas, and lake areas in western North America that can be used to calculate mercury retention rates. They categorized this data using the North American ecoregion framework (CEC 1997). Ecoregions are defined by areas with similar biotic and abiotic properties, such as topography, land use, vegetation, and soil composition. Because the sediment mercury accumulation method of determining mercury retention rate requires data from similar environments, this framework can be used to select appropriate data to calculate the Crooked Creek watershed mercury retention rate.

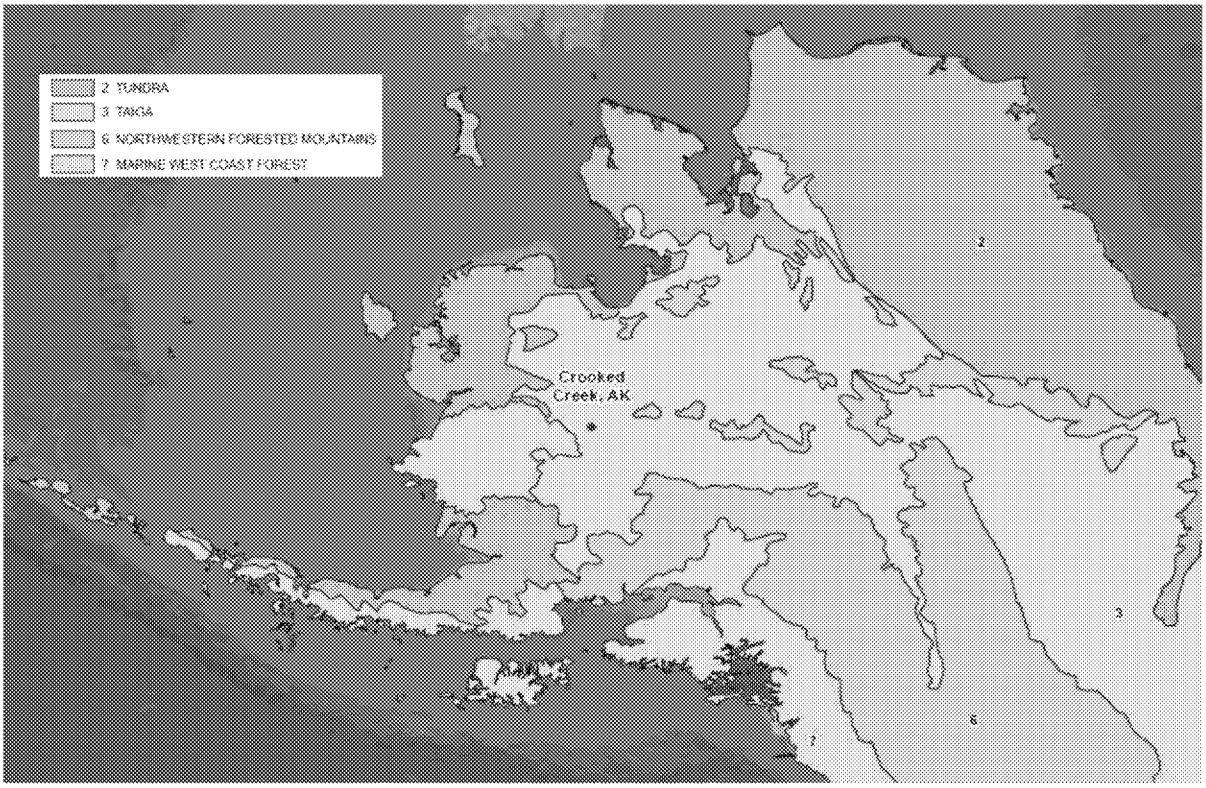


Figure 3.1-2. Distribution of level 1 ecoregions in Alaska (CEC 1997).

Data selected for the determination of the Crooked Creek watershed mercury retention rate were:

- From the Taiga, Northwestern Forested Mountains, and Marine West Coast Forest ecoregions
- From Alaska and northern Canada
- From watersheds undisturbed by human activity
- Sediments deposited between 1990 and 2000 based on age-dating

These criteria were used to ensure that the data used were representative of the Crooked Creek watershed. The rationale for these criteria follows.

Data from the ecoregions in Alaska similar to the Crooked Creek watershed were selected. The Taiga (3) ecoregion was included because Crooked Creek is located within the Taiga (3) ecoregion (Figure 3.1-2). The Taiga ecoregion is subarctic and covered by patchwork forests, shrublands, and wetlands, consistent with the climatic and plant cover characteristics of the Crooked Creek watershed area. The other ecoregions represented in Alaska are Tundra (2), Northwestern Forested Mountains (6), and Marine West Coast Forest (7) (Figure 3.1-2). The Northwestern Forested Mountains are characterized primarily by mountainous topography, with diverse vegetation depending on altitude and latitude including evergreen forests dominating at higher elevations. The Marine West Coast Forest ecoregion contains mountainous topography, and plant communities range from coastal rainforests to evergreen alpine communities, depending on latitude and precipitation level. Both these ecoregions are similar to the Crooked Creek watershed in their mountainous topography and evergreen forests. However, the Tundra ecoregion is characterized by extensive permafrost, particularly in the area from which the data are available in the far north of Alaska above the Arctic circle. Because the Crooked Creek watershed contains only some discontinuous permafrost, the Tundra samples were not used in the retention calculation. Therefore, data from the Taiga, Northwestern Forested Mountains, and Marine West Coast Forest ecoregions are used in the analysis. Only data from Alaska and northern Canada in the selected ecoregions were used to remove differences due to latitude that may be inconsistent with the Crooked Creek watershed.

Drevnick et al. classified data by the degree to which the watershed is disturbed by human activity. Due to the remote, sparsely inhabited nature of the Crooked Creek watershed, only undisturbed watershed data were used (a watershed disturbance index of 0). Drevnick et al. present data from multiple depth intervals sectioned from sediment cores. These depth intervals represent historical sediment deposition to the lake bottom, and the sediments were analyzed to determine the decade in which each section was deposited. Only sediment data dated between 1990 and 2000 were used to obtain a recent mercury retention rate (there were insufficient samples from after 2000 to obtain a regression).

Figure 3.1-3 shows the regression of the selected data used to calculate the mercury retention rate. The rate of mercury accumulation in lake sediment is plotted against the catchment area ratio (non-lake area of the watershed)/(lake area). The p value of the regression, the rate of atmospheric mercury deposition, and the mercury retention rate (calculated based on regression parameters as described in Section 3.1.2.1) are presented in the associated table. The p value of the regression is less than 0.05, indicating that the regression is statistically significant. The rate of atmospheric mercury deposition is calculated to be 5.1 $\mu g/m^2$-year, which is largely consistent with the baseline atmospheric mercury deposition for the site. The mercury retention rate for the Crooked Creek watershed was determined to be 93%. This retention rate is consistent with literature values of mercury retention rates in large (i.e., greater than 1,000 ha) forested watersheds at sub-arctic latitudes, which had an average retention rate of 92% (Brigham et al. 2009).

p value	R Sq.	Hg Deposition Rate (ug/m2/yr)	Hg Retention (%)
0.012	0.68	5.1	93

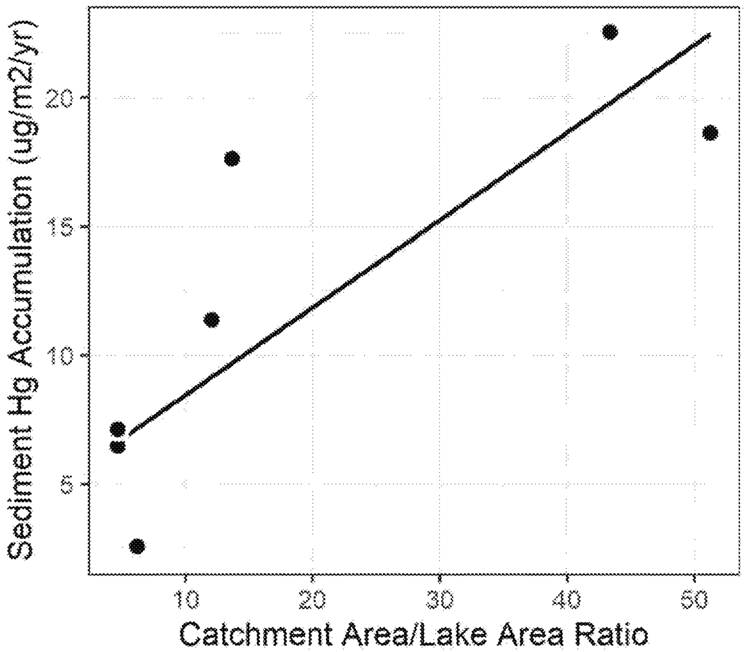


Figure 3.1-3. Mercury accumulation in lake sediment versus the catchment area/lake area ratio.

3.1.3 Geochemical Fingerprinting of Mercury Sources

3.1.3.1 Conceptual Framework

Mercury in Crooked Creek under baseline conditions is associated with the suspended solid load (Arcadis 2020). The mercury in this solid phase is from both atmospheric deposition and geologic sources. Understanding the mercury mass balance in the Crooked Creek watershed requires quantifying the mercury attributable to each source. A geochemical fingerprinting method was applied to evaluate the relative contributions of atmospheric and geologic mercury sources to soils, sediments, and suspended particulates throughout the watershed. The geochemical fingerprinting evaluation was used to corroborate the evaluation of mercury source contribution determined in the mass balance analysis (Section 3.3).

As bedrock weathers and erodes, it supplies solid material found in soils and sediments throughout a watershed. The ratio of mercury to a geologic tracer element in the bedrock acts as a geologic signature. The tracer element is typically a metal that is enriched in the geology and does not have any other significant source in the local environment (including atmospheric deposition), and therefore reflects geologic inputs. Aluminum is frequently used as the geologic tracer element (Chen et al. 2007; Siqueira et al. 2018). The ratio of mercury to tracer metal is then measured in other environmental particulate phases and compared to the bedrock ratio. If the ratio is greater in the particulate phase than in the bedrock, the excess mercury is attributable to atmospheric sources (Hissler and Probst 2006; Guédron et al. 2012).

3.1.3.2 Methods

Representative waste rock data collected from the mine site (SRK 2011) was used to determine the background mercury and aluminum concentrations for local bedrock. Sedimentary rock, igneous rock from intrusions, unconsolidated material, and material of unknown provenance were collected and analyzed for mercury and aluminum by ALS laboratory. To determine metal concentrations, rocks and other solid material samples must be digested (i.e., broken down into a liquid phase suitable for chemical analysis). The method used to digest the material affects how much and which components of the sample is broken down. Samples for mercury analysis were digested using a hot aqua regia digest, whereas samples for aluminum analysis were digested using a mixed acid digest that included hydrofluoric acid (HF). The HF digest is a stronger digestion method that dissolves the aluminosilicate matrix of the material, which is required to release all the aluminum from the sample and obtain an accurate geologic signature.

To define the Crooked Creek watershed bedrock mercury-to-aluminum ratio, the data set was enhanced by excluding data from unknown provenance and from igneous intrusions. The watershed is dominated by the sedimentary rocks of the Kuskokwim group (USACE 2018). Therefore, the sedimentary rock samples from the study (which represent Kuskokwim group material) are representative of the local bedrock. Because igneous intrusions are uncommon throughout the watershed (USACE 2018), igneous rock data were excluded from this analysis. Unconsolidated samples tend to be further along in the erosion process, and therefore represent material that contributes to forming soils and sediments. There were 830 sedimentary and unconsolidated samples with data that contributed to the bedrock ratio estimate.

Soil, sediment, and suspended particulate samples were collected during the 2021 sampling event (as described by Arcadis 2021) to determine the contributions of atmospheric versus geologic mercury in surface materials throughout the watershed. Suspended particulates were collected because elevated mercury in Crooked Creek surface water is correlated with the suspended solid phase (Arcadis 2020). Previously collected soil and sediment data could not be used for the geochemical fingerprinting because they were not digested using an HF digest, and therefore aluminum concentrations would be underestimated.

Soil samples were collected from twelve locations around the watershed. Sediment samples were collected from four locations in the Crooked Creek main stem. Soil and sediment samples collection methods were consistent with previous studies (Arcadis 2007). Suspended particulates were collected at two previously established sampling locations (CCAC and CR0.3) over seven collection events. Suspended particulates were collected from Crooked Creek surface water by passing water through 47 mm polyvinylidene difluoride (PVDF) filters. The suspended particulates remain on the filter, and the filter is retained for analysis. Two filters were collected at each sampling location per event and the volume of water passed through each filter was measured. A sample for total suspended solids (TSS) determination was also collected at the time of suspended particulate sampling. The concentration of metals in suspended particulates was determined by calculating the sample mass present on each filter. The TSS concentration collected simultaneously with the filters was multiplied by the volume of water passed through each filter to obtain a mass of suspended particulates. The mass of metal measured on each filter was divided by the mass of suspended particulates to calculate the concentration. Soil and sediment samples were subsampled for mercury digestion (hot aqua regia) and aluminum digestion (mixed acid with HF) and analyzed by ALS. These digestions were identical to those done for the waste rock by the same laboratory. Due to the specialized nature of the digestion and analysis, the filters containing suspended particulates were analyzed by Brooks Applied Labs. One filter from each sampling event was digest by a hot aqua regia digest and analyzed for mercury; the other was digested by a mixed acid digest with HF and analyzed for aluminum.

Because the filters were included in the suspended particulate digestion, mercury and aluminum present in the filter could be released. This possibility was evaluated using the equipment blanks (i.e., ultrapure water being passed through the filtration apparatus and the filter digested and analyzed for mercury and aluminum) (Table 3.1-1). If the concentration in a filter that contains sample material is similar to concentrations in the blanks, then the sample concentration is too low to be distinguished from the filter. To determine if any samples had concentrations too low to use in the analysis, the highest concentrations of mercury and aluminum in the blank filters were compared to the concentrations in each sample filter. One sample (collected from CR0.3 on 7/3/21) had a mercury concentration below the maximum blank concentration and was therefore excluded from further analysis.

Table 3.1-1. Suspended particulate method validation

Chemical	Result Unit	Blank Maximum	Sample Minimum
Aluminum	ug/filter	25	51.8
Mercury	ng/filter	0.39	0.441

3.1.3.3 Results

The bedrock and sample mercury-to-aluminum ratios are presented in Figure 3.1-4. Ratios of mercury to aluminum in each sample were calculated as the mass ratio times 10,000 to attain numbers of a reasonable order of magnitude. Each point represents one sample. The gray boxes graphically denote summary statistics for the data distribution: the center line represents the median, while the upper and lower edges of the box represent the first and third quartiles of the data, respectively. Half of all the data points within a distribution fall within the boxed area. The mercury-to-aluminum ratios in the soils, sediments, and suspended particulates are similar to one another, and are well within the range of the waste rock values. Since the mercury-to-aluminum ratios in the soils and sediments are comparable to the ratios in the bedrock, the contribution of atmospheric mercury was too small to be detected beyond the contribution of the background geologic source. This indicates that the proportion of atmospheric mercury in solids, sediments, and suspended solids is negligible or nondetectable relative to geologic sources. This empirical evidence corroborates the finding in the mercury mass balance that atmospheric contribution of mercury is small relative to the geologic component (Section 3.3.4).

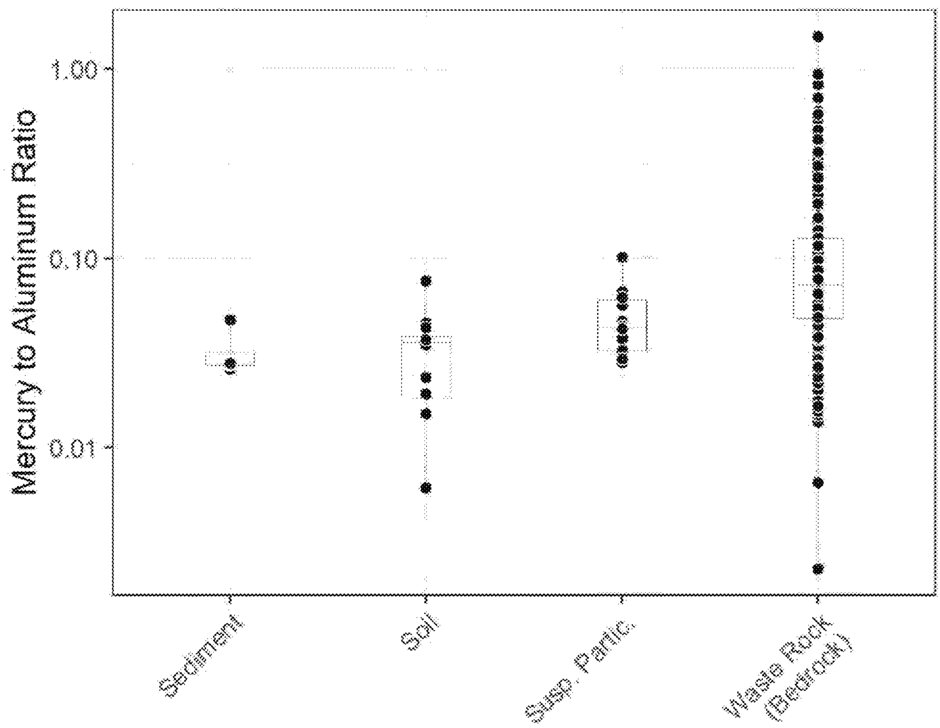


Figure 3.1-4. The ratio of mercury to aluminum (as a mass ratio times 10,000) for each sample.

3.2 Mercury Emissions and Atmospheric Deposition

This section presents an updated and more accurate estimate of the Project's mercury emissions and an updated modeling analysis, resulting in a more accurate estimate of the Project's mercury deposition compared to that included in the FEIS.

3.2.1 Updates to Particle Size Distribution and Deposition Parameters used in Air Deposition Modeling

3.2.1.1 Background

The processes that govern dry and wet deposition of particulate species are strong functions of the particle size. For particles greater than about 1 µm in size, larger particles dry deposit much more readily than smaller particles (e.g., Lin et al. 1994; Bergametti et al. 2018; Emerson et al. 2020). For example, the deposition velocity of a 1 µm particle is about ten times lower than that of a 10 µm particle (e.g., Seinfeld and Pandis 2016; Bergametti et al. 2018; Emerson et al. 2020). Scavenging coefficients[6] (constant parameters) that affect the removal of particles through wet deposition show a similar trend with particle size (e.g., Wang et al. 2010).

In the previous modeling conducted with the CALPUFF[7] air quality dispersion and deposition model for the FEIS (Environ 2015), it was assumed that all the particulate mercury emissions from the Project were in the very coarse size fraction, that is larger than 10 µm with a geometric mean diameter of 15 µm and a standard deviation of 3 µm. This approach, which did not account for the actual size distribution of the Project particulate matter (PM) emissions, was conservatively high for deposition

[6] Scavenging coefficients are deposition parameters used to represent how much of the atmospheric mercury gets washed out by rain or snow.
[7] CALPUFF is a non-steady state puff dispersion model that has been applied for mercury deposition in other studies.

within the Crooked Creek watershed because smaller particles were assumed to deposit and to be scavenged at the same rate as larger particles within the Crooked Creek watershed whereas, in fact, smaller particles would be atmospherically dispersed and diluted over large distances. As a consequence of this conservative assumption, total mercury deposition to the Crooked Creek watershed from the Project was significantly overestimated in the FEIS modeling.

Using particulate mercury deposition parameters that are more accurate and more representative of the particulate mercury emissions from the Project results in a more representative mercury deposition estimate than the conservative estimates from the previous modeling study, as described below.

3.2.1.2 Modeling Using Actual Particle Size Distribution and Size-Dependent Deposition Parameters

3.2.1.2.1 Particle Size Distribution

The emissions of PM emissions modeled are in three size categories[8]: $PM_{2.5}$, $PM_{2.5-10}$, and PM_{10+} (i.e., fine particles less than 2.5 μm, coarse particles in the 2.5 μm to 10 μm size range, and very coarse particles larger than 10 μm, respectively). Using the mercury content of the PM emissions from the various Project source categories and the mass fraction in each size bin, total particulate mercury emissions for each source category emitting particulate mercury were speciated into the three size categories. Table 3.2-1 below shows the mass fraction of total particulate emissions in the three size categories from the various activities associated with the Project (source: Air Sciences 2021). These sources include all typical mining activities such as drilling, blasting, extraction and transfer of ore and waste rock, associated equipment use, and wind erosion of open surfaces.

Table 3.2-1. Modeled size distribution of particulate mercury emissions from mining activities at the Project.

Activity	Size Bin		
	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10+}
Drilling	3%	49%	48%
Blasting	3%	49%	48%
Material Handling (Loading and Unloading)			
Ore Loading	7%	40%	53%
Ore Unloading	7%	40%	53%
Waste Loading	7%	40%	53%
Waste Unloading	7%	40%	53%
Material Hauling			
Ore Hauling	2%	22%	76%
Waste Hauling	2%	22%	76%
Dozer Use	11%	7%	82%
Grader Use	3%	41%	56%
Water Truck Use	2%	22%	76%
Wind Erosion of Exposed Surfaces			
Tailings Beach (Dry)	8%	43%	50%

[8] $PM_{2.5}$ refers to particles smaller than 2.5 μm. PM_{10} refers to particles smaller than 10 μm. PM_{10+} refers to particles larger than 10 μm.

Activity	Size Bin		
	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10+}
Haul Roads	8%	43%	50%
Access Roads	8%	43%	50%
Waste Rock Facility	8%	43%	50%
Stockpiles	8%	43%	50%
Average	**3%**	**25%**	**72%**

3.2.1.2.2 Deposition Parameters

Once the particulate mercury emissions are divided into different size bins, they can be modeled as separate species in CALPUFF with size-dependent parameters for the dry and wet deposition. As discussed above, three size bins ($PM_{2.5}$, $PM_{2.5-10}$ and PM_{10+}) were used to model the particulate mercury (fugitive dust) in CALPUFF. Dry deposition velocities for particulate mercury in the three size bins are then calculated internally in CALPUFF based on the provided diameters and standard deviations.

Using three different species to represent the size-distributed particulate mercury emissions allows the use of size-specific scavenging coefficients for wet deposition calculations. Scavenging coefficients are a function of particle size, with orders of magnitude differences between the fine and very coarse particle sizes. Table 3.2-2 shows the scavenging coefficients for liquid and frozen precipitation for the three particle sizes based on bulk parameterizations of particle scavenging coefficients from the literature (Wang et al. 2014). Note that these rates are for a nominal precipitation rate of 1 mm/hr, and CALPUFF internally multiplies by the actual precipitation rate. The previous CALPUFF modeling assumed very coarse particles for particulate mercury and used coarse particle scavenging coefficients as shown in Table 3.2-2. Also shown are the geometric mean diameter and standard deviation[9] used to represent each size bin. These two parameters together are used to represent the distribution of potential particle sizes within a given size bin.

Table 3.2-2. Particle size parameters and precipitation scavenging coefficients used in CALPUFF deposition modeling.

Parameter	FEIS Modeling	Current Modeling		
		$PM_{2.5}$	$PM_{2.5-10}$	PM_{10+}
Geometric Mass Mean Diameter*	15 µm	0.5 µm	5.0 µm	17.32 µm
Geometric Standard Deviation*	3 µm	1.495	1.189	1.147
Liquid Precipitation Scavenging Coefficients	$1x10^{-2}$ (sec)$^{-1}$	$1x10^{-6}$ (sec)$^{-1}$	$2x10^{-4}$ (sec)$^{-1}$	$6x10^{-4}$ (sec)$^{-1}$
Frozen Precipitation Scavenging Coefficients	$3x10^{-3}$ (sec)$^{-1}$	$2x10^{-5}$ (sec)$^{-1}$	$1x10^{-3}$ (sec)$^{-1}$	$5x10^{-3}$ (sec)$^{-1}$

* The geometric mean diameters (mean) and geometric standard deviations (SD) were selected such that each size bin extends approximately from mean – 4SD to mean + 4SD when logarithmic values are used, consistent with how CALPUFF treats the lognormal size distribution of particles. For normally distributed data, 99.99% of the values are within four times SD (i.e., 4SD) of the mean diameter. The PM_{10+} size bin was assumed to extend to PM_{30}, the size typically used for total suspended particles. The default parameterization of CALPUFF is applied where it uses the geometric mass mean diameter and 4SD to calculate the minimum and maximum particle sizes of each size bin, divides that bin into multiple sub-bins and performs the deposition calculations for each of those sub-bins. Log(min. of a size bin) = log(mean diameter) – 4log(SD). Log (max. of a size bin) = log(mean diameter) +4log(SD).

[9] Standard deviation is a measure of the amount of variation in a set of values, in this case, particle sizes.

3.2.2 Fugitive Gaseous Elemental Mercury Emissions from the Tailings Storage Facility

In the FEIS, vapor mercury emissions (in the form of gaseous elemental mercury) from the proposed Donlin Gold Tailings Storage Facility (TSF) were estimated using methods similar to the studies for two active gold mines in Nevada (Eckley et al. 2011a, 2011b) but using Donlin-specific data and accounting for differences in solar radiation and geochemistry/mercury content between Donlin Gold and the Nevada mines.

Tailing effluent is input to tailings impoundments as a liquid slurry to specific areas over time resulting in heterogeneous surface moistures. The Donlin Gold TSF will consist of a pond (inundated solution) and beach. The purpose of this section is to describe the evaluation of mercury emissions from both the pond and beach portions of the TSF.

3.2.2.1 TSF Pond Mercury Emission Flux

The methodology to estimate mercury emissions from the inundated tailings pond assumes a linear dependency between mercury emission flux and mercury solution concentration. The FEIS used a pond mercury concentration of 0.315 mg/L which was derived from the measured mercury concentrations in tailings material (0.00004 mg/L for liquid and 0.7 g/ton for solid) and other process parameters from the Feasibility Pilot Study (2007 Phase 2; SRK, 2012), namely, a tailings slurry water percentage of 64% and solids and slurry specific gravity of 2.76 and 1.25, respectively.

In this analysis, updated information on the tailings concentration that became available since the modeling exercise to support FEIS development (Environ 2015) was used. Specifically, the updated Water Resources Management Plan (WRMP; SRK 2017) provides a soluble mercury content of 0.073 mg/L derived from geochemical modeling of the tailings filtrate water from the Feasibility Pilot Phase 2 study.[10] The outcome of the geochemical model is still conservative because it did not account for Donlin Gold's plan to use mercury settling-enhanced reagents.[11]

The resulting mercury emission flux using the estimated mercury concentration in the Donlin tailings pond of 0.073 mg/L is 3,510 ng/m^2-day (compared to the 0.315 mg/L mercury concentration and 15,147 ng/m^2-day flux found in the FEIS). Consistent with the previous calculation in the FEIS, this emission flux is assumed to occur during the open water season only. During the winter months, ice cover is expected to reduce the emission fluxes to zero.

3.2.2.2 TSF Beach Mercury Emission Flux

The mercury emission flux from the TSF beach is correlated with mercury substrate concentration, surface moisture and meteorological parameters (solar radiation, temperature, and relative humidity).

In the FEIS, the mercury emission flux from the beach (all of which was considered wet) was estimated from a linear correlation (e.g., logarithmic regression) relating mercury emission flux to the tailings material mercury concentration for two levels of solar radiation (low, <140 W/m^2; middle, 141-251 W/m^2). These correlations, while based on the Eckley et al. (2011b) study, were tailored to include only high moisture surface substrates[12] (i.e., > 5%) following Eckley (2011a)[13].

[10] The geochemical modeling was performed using the Geochemist's Workbench model (SRK 2017).

[11] A settling-enhanced reagent, such as the University of Nevada Reno (UNR)-921 reagent, promotes precipitation of mercury in solution into a stable mercury sulfide (HgS) solid. As such it acts to stabilize mercury in TSF water and reduce potential volatilization. Actual pond mercury concentrations at Donlin tailings pond using the UNR reagent are anticipated to be less than 0.010 mg/L based on reductions observed at Barrick's Pueblo Viejo facility using the UNR-921 reagent. Nonetheless, in the emissions calculation presented here, a more conservative TSF pond mercury concentration of 0.073 mg/L was used.

[12] Correlations derived from Eckley et al. included several surface mine types: tailings, waste rock, leach pad, and pits.

[13] As noted in Eckley et al. (2011a), the decision to use 5% moisture as a differentiator between wet and dry fluxes was based on field observations indicating that during dry weather conditions the average soil moisture was 1±1%; however, during/after precipitation the moisture ranged from 5 to 17%.

The FEIS analysis did not take into account that a portion of the TSF beach would be dry. In fact, however, the locations of tailings discharge spigots will vary by year to adhere to design criteria resulting in sections near active spigots being wet while leaving other sections of the beach area dry. The current analysis more accurately divides the beach sections into wet and dry areas.

In this study, the wet beach area is set to one-third of the entire beach area (33%) based on the operational update for the rate of movement of the active beach area (Donlin Gold 2015). The other 67% of the beach area is considered dry. The FEIS methodology of using mercury emission flux correlation with mercury substrate concentration is applied; however, the correlations differ between the wet and dry beach recognizing that moisture level affects the mercury emission flux. The same Donlin mercury tailings solid concentration of 0.7 mg/g applied in the FEIS is also applied here for both wet and dry beach. During the months of November to March, the beach is expected to be covered with snow and/or ice; hence, emission fluxes from the wet and dry beach are set to zero during those months.

The dry beach flux correlations are directly from the Eckley (2011a, 2011b) correlations for the two Nevada mines;[14] the resulting emission fluxes were averaged to represent dry beach mercury emission fluxes at Donlin.

The wet beach emission flux correlations are derived from the Eckley data for the two mines using the FEIS methodology.[15]

Table 3.2-3 summarizes mercury emission flux correlations and resulting emission fluxes used in this study.

[14] The logarithmic regressions were derived from empirical data from several major mine surfaces (including open pits, waste rock dumps, leach pads, ore stockpiles, and tailings impoundments) and expressed as a function of substrate Hg concentration and solar radiation (Eckley et al. 2011a; Figure 2).

[15] Table 1 from Eckley et al. (2011b) provided mean Hg emission flux and associated ancillary parameters at the two Nevada mines for all surface types. These data after excluding very dry surface substrates (i.e., <5% moisture) formed the basis of the derived linear correlations for the wet beach. The rationale for combing data from both mines and all surface types was to utilize the largest available dataset to derive the most robust empirical relationship between surface moisture, substrate Hg concentration and Hg flux (for fixed solar radiation levels). The multivariate regression obtained is specific to each solar bin:

Low solar (<140 W/m^2) : log Hg flux = 0.55 log Hg +0.061 (% moisture) + 2.49

Middle solar (141-251 W/m^2): log Hg flux = 0.56 log Hg +0.066 (% moisture) + 2.98

Note that the flux regressions are slightly different between the current study and the FEIS because the FEIS put a data point in the middle solar bin when it should have been in the low solar bin, with the FEIS thus resulting in a conservative high estimate. As in the case of the FEIS, the wet beach moisture content was assumed to be the same as the average substrate moisture at the Twin Creeks tailings impoundment (19.1%), and the regression equation was evaluated at that level to derive a linear regression with substrate Hg concentration as the independent variable and Hg flux as the dependent variable (as shown in Table 3.2-3).

Table 3.2-3. Correlation between mercury emission flux (in ng/m^2-day) and mercury substrate concentration (mg/g) for low and middle solar regimes.

Solar Radiation Bin	Dry		Wet	
	Correlations	Emission Flux for Hg of 0.7 mg/g	Correlations	Emission Flux for Hg of 0.7 mg/g
FEIS				
Low Solar	-*	-*	log Hg flux = 0.60 log Hg + 3.24	1,396
Mid Solar	-*	-*	log Hg flux = 0.54 log Hg + 4.36	18,902
This Study				
Low Solar	Twin Creek: log Hg flux = 0.59 log Hg + 2.59 Cortez: log Hg flux = 0.67 log Hg + 2.49	279 (average of Twin Creek and Cortez)	log Hg flux = 0.55 log Hg + 3.65	3,671
Mid Solar	Twin Creek: log Hg flux = 0.60 log Hg + 2.88 Cortez: log Hg flux = 0.71 log Hg + 2.69	496 (average of Twin Creek and Cortez)	log Hg flux = 0.56 log Hg + 4.24	14,232

*Dry section not differentiated from wet section in FEIS.

3.2.2.3 Total TSF Mercury Emissions

Annual TSF mercury emissions were derived by multiplying mercury emission fluxes by tailings surface areas. Tailings mercury emission fluxes were assumed to be constant throughout the mine life; total surface areas increase year over year. Peak surface area is reached in year 28 (end of operation; see Figure 3.2-1) and this year was selected as a conservative (high) estimate of tailings mercury emissions impacts. Updated mercury emission estimates by operating year are shown in Table 3.2-4. The annual emissions totals shown are the sum of the monthly emissions taking into account the seasonal variations. The annual emissions peak over the mine life is 7.48 kg/yr occurring in year 28. Tailings emissions are expected to decrease after closure because of the cap placed over the TSF surface.

All gaseous mercury emissions from the TSF would be in the elemental form, Hg(0), because this is the primary form of mercury that volatilizes.

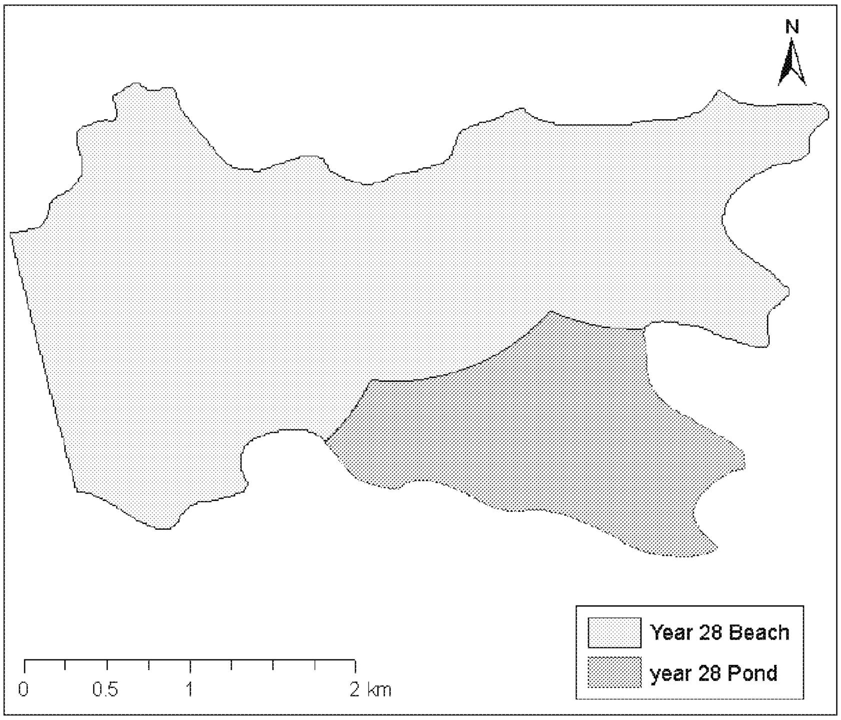


Figure 3.2-1. Tailings Storage Facility spatial extent in year 28.

Table 3.2-4. Annual surface areas and estimated gaseous mercury emissions at the TSF.

Year	Area (acre)			Hg Emissions (kg/yr)		
	Beach	Pond	Total	Beach	Pond	Total
1	111	192	303	0.38	0.58	0.96
5	428	430	858	1.47	1.30	2.77
9	719	503	1222	2.47	1.52	3.99
13	934	581	1515	3.21	1.76	4.97
17	1107	654	1761	3.81	1.98	5.79
21	1192	780	1972	4.10	2.36	6.46
25	1333	808	2141	4.58	2.44	7.03
28	**1733**	**501**	**2234**	**5.96**	**1.52**	**7.48**

3.2.2.4 Summary of TSF Mercury Approach and Results

The FEIS overestimated TSF mercury emissions. The current analysis updated the TSF mercury emissions calculations as follows:

- The pond mercury concentration derived from geochemical modeling is 0.073 mg/L (compared to 0.315 mg/L used in the FEIS). The mercury emission flux for the tailings pond decreased from 15,147 ng/m^2-day to 3,510 ng/m^2-day.
- The mine plan indicates that approximately 33% of the entire beach area will be wet and 67% will be dry (100% wet beach was used in the FEIS). The dry beach flux correlations are directly from the Eckley et al. (2011a, 2011b) correlations for the two Nevada mines. The wet beach emission flux correlations are derived using the FEIS methodology with minor corrections.
- The TSF surface area is based on the end of operation year (year 28) with the peak area.

Table 3.2-5 summarizes the resulting peak TSF emissions. The updated annual mercury emissions are 1.52 kg/yr from the pond (81% reduction from the FEIS) and 5.96 kg/yr from beach (70% reduction from the FEIS). Total TSF mercury emissions are 7.48 kg/yr, which is a 73% reduction from the FEIS. All of the mercury is in the gaseous elemental form, Hg(0).

Table 3.2-5. Updated annual estimated gaseous mercury emissions at the Donlin TSF.

TSF	FEIS		Updated		Emissions Change (%)
	Flux (ng/m^2-day)	Emissions (kg/yr)	Flux (ng/m^2-day)	Emissions (kg/yr)	
Pond	15,147	8.13	3510	1.52	-81%
Beach	1,396-18,902	19.65	279-14,232	5.96	-70%
Total		27.78		7.48	-73%

3.2.3 Fugitive Gaseous Elemental Mercury Emissions from the Ore Stockpiles, Pit and Waste Rock Facility

The fugitive gaseous elemental mercury (i.e., Hg(0)) emissions from the ore stockpiles, pit, and WRF were estimated using the same methodology as in the Donlin FEIS but with updates to the following data:

- The average mercury concentration in the source materials
- The area of each source
- The average solar radiation

The average mercury concentration in each of the three sources (waste rock facility, pit, ore stockpiles) were estimated in the FEIS using a resource block model[16]. The data were updated using the geometric mean of ICP analysis of 18,484 ore and 41,072 waste rock samples from Donlin (2014). The use of the geometric mean is consistent with the method used for assessing the concentrations of other metals in the ore in Donlin Gold Prevention of Signification Deterioration (PSD) permitting (Air Sciences, 2021). Table 3.2-6 shows the updated mercury concentration for each source.

[16] A block model is a geological computer model that shows the three-dimensional location of each type of rock.

Table 3.2-6. The mercury concentration modeled for each source in the current analysis.

	Ore stockpiles	Pit	Waste rock facility
Hg Concentration (µg/g)	1.27	0.695	0.59

Incoming solar radiation affects the volatilization of mercury from these surfaces. The solar radiation data was updated using recent meteorological data at the Camp monitor station collected during August 2020 to July 2021. The monthly averaged solar radiation is shown in Table 3.2-7 below.

Table 3.2-7. Monthly averaged solar radiation at Camp from August 2020 to July 2021.

Month	Mo Avg. of Daily Mean (W/m^2)	Solar Category	Season
Aug-20	161	Middle	Summer
Sep-20	93	Low	Fall
Oct-20	46	Low	Fall
Nov-20	15	Low	Fall
Dec-20	5	Low	Winter
Jan-21	13	Low	Winter
Feb-21	39	Low	Winter
Mar-21	89	Low	Spring
Apr-21	179	Middle	Spring
May-21	237	Middle	Spring
Jun-21	187	Middle	Summer
Jul-21	142	Middle	Summer

Using these updated data and the same regression correlations as in the FEIS, the mercury flux per unit area and the monthly mercury emissions were calculated and are shown in Table 3.2-8. Gaseous emissions from these sources would be in the form of Hg(0) as that is the primary form that volatilizes from surfaces. The total mercury emissions from these sources is estimated to be 1.74 kg/yr.

Table 3.2-8. Estimated fugitive gaseous elemental mercury emissions from the Ore Stockpiles, Pit and Waste Rock Facility.

Month	Solar	Hg emissions (ng/m^2-day)			Hg emissions (kg/m^2-month)			Hg emissions (kg/month)		
		Ore stock	Pit	WRF	Ore stock	Pit	Waste rock	Ore stock	Pit	WRF
Jan	Low	363	242	217	1.12E-08	7.51E-09	6.73E-09	9.28E-03	4.44E-02	6.57E-02
Feb	Low	363	242	217	1.02E-08	6.78E-09	6.08E-09	8.38E-03	4.01E-02	5.93E-02
Mar	Low	363	242	217	1.12E-08	7.51E-09	6.73E-09	9.28E-03	4.44E-02	6.57E-02
Apr	Middle	580	378	337	1.74E-08	1.13E-08	1.01E-08	1.44E-02	6.71E-02	9.86E-02
May	Middle	580	378	337	1.80E-08	1.17E-08	1.04E-08	1.49E-02	6.94E-02	1.02E-01
Jun	Middle	580	378	337	1.74E-08	1.13E-08	1.01E-08	1.44E-02	6.71E-02	9.86E-02
Jul	Middle	580	378	337	1.80E-08	1.17E-08	1.04E-08	1.49E-02	6.94E-02	1.02E-01
Aug	Middle	580	378	337	1.80E-08	1.17E-08	1.04E-08	1.49E-02	6.94E-02	1.02E-01
Sep	Low	363	242	217	1.09E-08	7.27E-09	6.51E-09	8.98E-03	4.30E-02	6.35E-02
Oct	Low	363	242	217	1.12E-08	7.51E-09	6.73E-09	9.28E-03	4.44E-02	6.57E-02
Nov	Low	363	242	217	1.09E-08	7.27E-09	6.51E-09	8.98E-03	4.30E-02	6.35E-02
Dec	Low	363	242	217	1.12E-08	7.51E-09	6.73E-09	9.28E-03	4.44E-02	6.57E-02
Total (kg/yr)	-	-	-	-	-	-	-	**0.137**	**0.646**	**0.952**

Numbers may not add exactly due to rounding.

3.2.4 Stack Emissions

Table 3.2-9 shows the Donlin process stack mercury emissions and their speciation in the FEIS and updates made in this analysis. The updated mercury emissions and mercury speciation profiles were obtained from Air Sciences (2021) who applied source-specific controlled mercury concentrations, stack flows, and annual maximum operations. Controlled mercury concentrations for the autoclaves and carbon regeneration kiln are based on adjustments to emissions data from Hatch (2014) using source test data from similar units at the Nevada Goldstrike Mine[17]. The remaining controlled mercury concentrations are based on the Nevada Mercury Control Program Permitting Guidance (NDEP 2016). The updated mercury speciation profiles are based on mercury speciation test data from the Goldstrike Mine.

Mercury emissions from boilers, heaters and incinerators at the Project which are relatively small and not previously modeled in the FEIS are now modeled and listed in Table 3.2-10. Mercury emissions estimates for stacks at these sources were obtained from Air Sciences (2021) who compiled this inventory using EPA AP-42 emissions factors for combustion of natural gas, ultra-low sulfur diesel and

[17] The Goldstrike mine provides a representative measure of expected mercury emissions from the Donlin Gold processing facility after adjusting for Donlin-specific source parameters (Air Sciences 2021)

dual fuel for the boilers/heaters and vendor guarantees for incinerators. A default mercury speciation of 50% Hg(0), 30% Hg(II), and 20% Hg(p) for boilers and heaters was applied following the EPA mercury modeling database[18] for the Mercury and Air Toxics Standards (MATS). A mercury speciation of 22% Hg(0), 58% Hg(II), and 20% Hg(P) for incinerators was applied also based on the same EPA mercury modeling database.

Table 3.2-9. Processing facility stack emissions.

Source Category	FEIS				Update			
	Hg total Emission (kg/yr)	Hg(0) (%)	Hg(II) (%)	Hg(p) (%)	Hg total Emission (kg/yr)	Hg(0) (%)	Hg(II) (%)	Hg(p) (%)
Autoclave 101	0.14	74.3%	7.2%	18.5%	0.29	80.0%	5.2%	14.9%
Autoclave 201	0.14	74.3%	7.2%	18.5%	0.29	80.0%	5.2%	14.9%
Carbon Regeneration Kiln	16.47	97.5%	1.5%	1.0%	3.97	79.8%	2.7%	17.5%
Electrowinning Cells	29.67	98.0%	0.8%	1.2%	7.03	97.6%	1.9%	0.5%
Retort	10.70	95.0%	2.5%	2.5%	0.68	88.1%	4.7%	7.2%
Induction Melting Furnace	0.74	99.0%	0.8%	0.02%	3.69	98.0%	1.3%	0.7%
Total	**57.87**	**97.2%**	**1.3%**	**1.5%**	**15.95**	**92.2%**	**2.2%**	**5.6%**

Numbers may not add exactly due to rounding.

Table 3.2-10. Emissions from boilers, heaters and incinerators.

Source Category	Annual Mercury Emissions (kg/yr)			
	Hg (Total)	Hg(0)	Hg(II)	Hg(p)
Boilers/Heaters	1.90	0.95	0.57	0.38
Incinerators	0.08	0.02	0.04	0.02
Total	**1.97**	**0.97**	**0.61**	**0.39**

Numbers may not add exactly due to rounding.

3.2.5 Fugitive Dust Emissions

Estimates of fugitive dust mercury emissions, i.e., mercury associated with particulate fugitive dust sources at the Project, were revised using updated particulate emissions data obtained from Air Sciences (2021) and applying the appropriate mercury concentrations for the corresponding source material type. The following mercury concentrations were used for the fugitive dust from each source group: pit concentration of 0.695 ppm, ore concentration of 1.27 ppm for ore stockpiles and processing facility, and the waste concentration of 0.59 ppm for WRF, TSF, and general Project area. These concentrations are same as those discussed in Section 3.2.3. This methodology is similar to that used in the FEIS with one key change (related to average versus peak year) discussed below. Table 3.2-11 shows the fugitive dust mercury emissions for the sources of fugitive dust evaluated in the FEIS and in this study. Additionally, Table 3.2-11 shows the source material types chosen for mercury

[18] https://gaftp.epa.gov/Air/emismod/2005/2005v4_3/

concentrations used in the emissions calculations and the relative spatial allocation of fugitive dust emissions (these are the same as the allocations used in the FEIS).

Fugitive dust (particulate) mercury emissions are higher than in the FEIS by about 61%. This increase is primarily because the FEIS modeling used mine life average emissions while the supplemental modeling analysis uses peak mine life emissions which, in sum, represent a conservative (high) estimate. The modeled emissions from the Donlin mine pit in the supplemental analysis are also conservatively high because they do not account for in-pit retention of dust particles which would lower the estimated mercury deposition of fugitive dust emissions from the Project.

Table 3.2-11. Fugitive dust emissions.

Source Category	Material Type for Hg Concentration	Pit	Ore Stockpile	WRF	TSF	Processing Facility	Project Area	FEIS Average Emissions over mine life (kg/yr)	This Study: Mine Peak Year Emissions (kg/yr)
Mining									
Drilling	Ore + Waste	100%						0.058	0.065
Blasting	Ore + Waste	100%						0.055	0.096
Ore Loading	Ore + Waste	100%						0.056	0.025
Ore Unloading	Ore		100%					0.026	0.014
Waste Loading	Ore + Waste	100%						0.130	0.148
Waste Unloading	Waste			100%				0.130	0.130
Ore Hauling	Ore + Waste	50%	50%					0.113	0.246
Waste Hauling	Ore + Waste	50%		50%				0.837	1.823
Dozer Use	Waste						100%	0.153	0.147
Grader Use	Waste						100%	0.016	0.023
Water Truck Use	Waste						100%	0.025	0.041
Wind Erosion of Exposed Surfaces and Access Road Traffic Dust									
Tailings Beach	Waste				100 %			0.005	0.002
Haul Roads	Waste						100%	0.008	0.001
Access Roads	Waste						100%	0.044	0.001
Waste Rock Facility	Waste			100%				0.029	0.009
Ore Stockpiles	Ore		100%					0.004	0.002
Overburden Stockpile	Waste						100%	0.000	0.000

Source Category	Material Type for Hg Concentration	Pit	Ore Stockpile	WRF	TSF	Processing Facility	Project Area	FEIS Average Emissions over mine life (kg/yr)	This Study: Mine Peak Year Emissions (kg/yr)
Ore Processing									
Crusher Circuit	Ore					100%		0.029	0.035
Ore Transfer	Ore					100%		0.020	0.024
Pebble Crusher	Ore					100%		0.017	0.021
Thermal Processes	Ore					100%		0.018	0.000
Laboratories	Ore					100%		0.009	0.009
Total (kg/yr)								**1.780**	**2.861**

Numbers may not add exactly due to rounding.

3.2.6 Summary of Project Emissions

A summary of the Project emissions is presented in Table 3.2-12 along with the emissions previously modeled in the FEIS. Following the emissions analysis discussed above, the total Project mercury emissions are estimated to be 30.0 kg/yr, lower than the FEIS estimate by 66%.

Table 3.2-12. Summary of estimated Donlin mercury emissions.

Source Category	Emissions Source	FEIS (kg/yr)				Updates (kg/yr)			
		Hg(0)	Hg(II)	Hg(p)	Total Hg	Hg(0)	Hg(II)	Hg(p)	Total Hg
Stacks	Processing Facility	56.20	0.80	0.90	57.90	14.71	0.35	0.89	15.95
Fugitive: Tailings Gaseous	Tailings Beach	19.65			19.65	5.96			5.96
Fugitive: Tailings Gaseous	Tailings Pond	8.13			8.13	1.52			1.52
Fugitive: Other Gaseous	Ore Stockpile	0.06			0.06	0.14			0.14
Fugitive: Other Gaseous	Pit	0.74			0.74	0.65			0.65
Fugitive: Other Gaseous	Waste Rock Facility	0.97			0.97	0.95			0.95
Fugitive Dust	Fugitive Dust			1.80	1.80			2.86	2.86
Stacks	Boilers, heaters, incinerators	-	-	-	-	0.97	0.61	0.39	1.97
Total	**Total**	**85.80**	**0.80**	**2.70**	**89.30**	**24.88**	**0.97**	**4.14**	**30.0**

Numbers may not add exactly due to rounding.

3.2.7 Project Atmospheric Deposition

Updated air deposition modeling was performed using CALPUFF (the same model applied for the FEIS analysis) and the updates to emissions and methods discussed above. The runoff capture and water management and treatment measures during operation of the Project (WRMP; SRK 2017) will reduce stream mercury mass loadings from Project-related and non-Project sources in certain watersheds. Figure 3.2-2 presents the areas at the Project where runoff will be managed, thus resulting in a reduction in mercury mass loadings. These areas include almost all the American Creek watershed, the TSF area within the Anaconda Creek watershed, and some smaller areas such as the South Overburden Stockpile which is northwest of the Anaconda Creek watershed. The Project mercury mass loading to Crooked Creek from each watershed depends on the size of the watershed and the relative location of the watershed to Project sources. The Project mercury deposition to watersheds outside the Crooked Creek watershed would be lower than within the watershed because of the atmospheric dispersion and dilution of mercury emissions from the Project with distance. The estimated Project deposition-related loading in the Crooked Creek watershed is presented in Section 3.3.5 in the context of the mercury mass balance analysis for Project conditions.

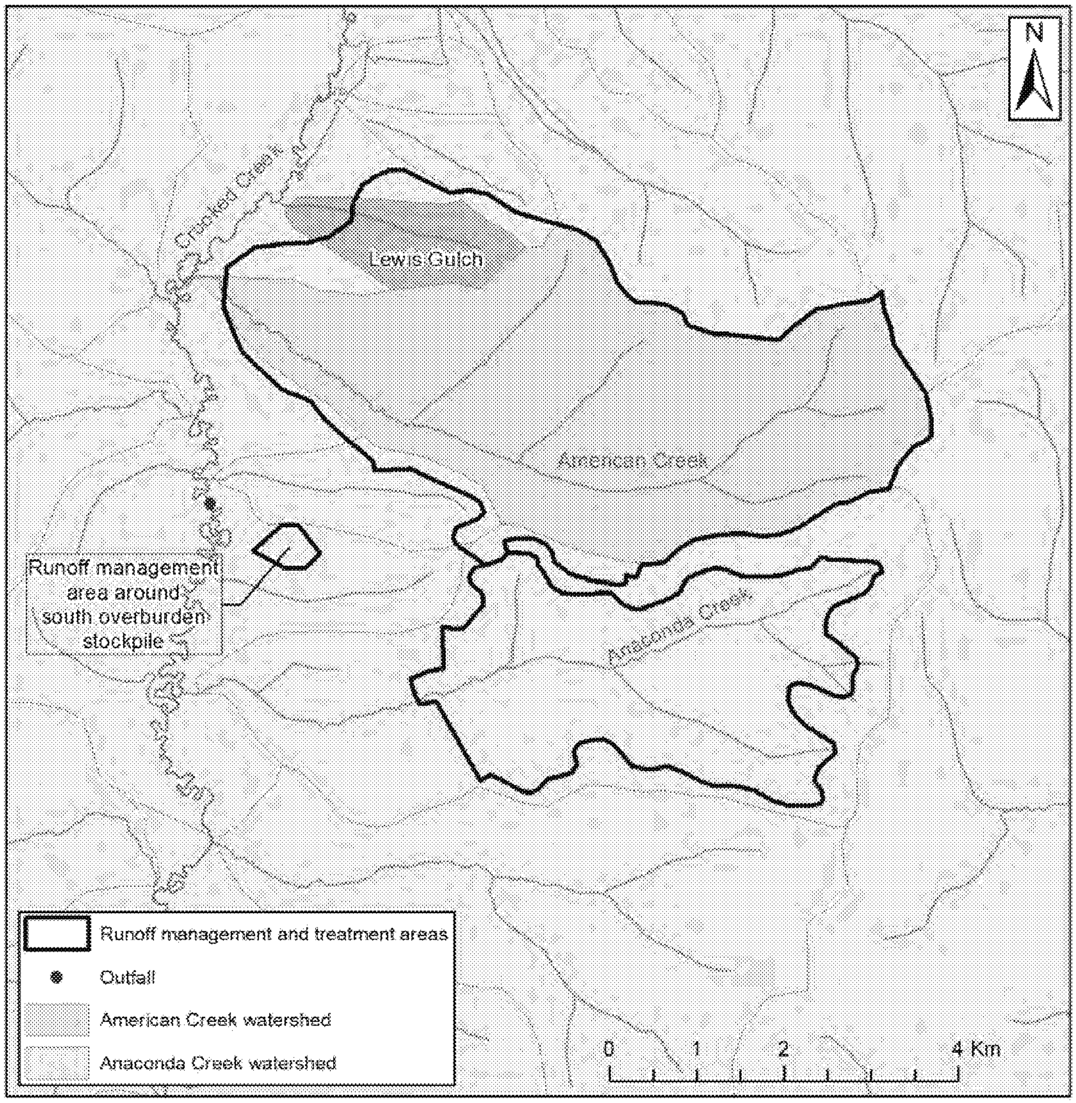


Figure 3.2-2. Runoff management and treatment areas.

3.3 Mercury Mass Loading Analysis

This section describes the methodology for estimating the baseline and project-related mercury mass loading to surface water in the Crooked Creek watershed. Historical flow and water quality data, along with new data collected in 2021, were used to develop models of long-term mercury mass loading at selected monitoring stations in the Crooked Creek watershed under baseline conditions. Then, a mass balance approach was employed to estimate the proportion of mass loading originating from geologic versus atmospheric sources. Understanding the relative mercury contribution from these sources enables more accurate predictions of potential impacts to water quality as a result of future Project emissions and implementation of runoff controls. This is important because previous analyses by Arcadis (2020) have shown a correlation between mercury concentrations and total suspended solids in the streams near the Project, again indicating a strong geologic rather than atmospheric source for the observed mercury concentrations in surface water.

3.3.1 Data Availability

The mercury mass loading analysis was performed at five monitoring stations within the Crooked Creek watershed (Figure 3.3-1).[19] These stations were selected because of the availability of concurrent flow and water quality data over multiple years, which is required for the calculation of mercury mass loading in surface water. Three of the stations are on tributaries near their confluence with Crooked Creek: Donlin Creek below Ophir Creek (DCBO), American Creek above the confluence with Crooked Creek (AMER), and Anaconda Creek above the confluence with Crooked Creek (ANDA). The two other stations are on the main stem of Crooked Creek: Crooked Creek above Crevice Creek (CCAC) has been used to monitor flow in Crooked Creek that drains the north-central portion of the watershed, and Crooked Creek above the Kuskokwim River (CCAK), is located just above the confluence with the Kuskokwim River and is the discharge point for the entire Crooked Creek watershed.

The available flow and mercury concentration measurements for the five monitoring stations are shown in Figures 3.3-2a to 3.3-2e of Appendix A. The mercury concentration figures also show the State of Alaska Water Quality Standard (AWQS) chronic value of 12 nanograms per liter (ng/L) in surface water. At station CCAK, the flow measurement data are from the nearby USGS gauging station #15304010, which has continuous records of daily flow from July 2007 through August 2021, with the exception of the most recent channel ice period between October 13, 2020 and May 3, 2021.[20] Missing daily flow data from the USGS gauge were estimated using daily averages calculated from prior periods. Flow data starting on May 4, 2021 is flagged as provisional by the USGS but appears consistent with the prior data record and was included to enable recent water sampling data to be incorporated in the loading analysis.[21]

For the remaining four stations, daily flow data were collected only during the open water period, generally May to October, for select calendar years dating from 2005 through 2012 in support of the FEIS.[22] Limited manual flow readings for the winter period are also available for certain locations.[23] Flow measurements with quality concerns were excluded, including: CCAC data from 2008 and 2009 that was flagged as irregular in the FEIS; DCBO data from 2010 that was inconsistent with concurrent readings at the USGS gage; CCAC data from 2010 to 2011 that appeared to have been estimated from flow at the USGS gage; and a small number of outlier measurements from AMER in 2011 and 2012.

[19] Figure was prepared based on geographic information system (GIS) files provided to Ramboll by Donlin.
[20] Data were downloaded from the USGS website.
[21] The provisional data has not been reviewed or edited by the USGS and may change in the future.
[22] Daily flow data in file "Donlin Daily Flow Data (1996-2011).xlsx," provided to Ramboll by Donlin.
[23] Manual flow data in file "Streamflow_2012-2015.zip," provided to Ramboll by Donlin via email on July 23, 2021

Surface water quality monitoring has been ongoing since at least 2005 in support of the FEIS and federal and State permitting processes. As shown in Figures 3.3-2a through 3.3-2e, total mercury sampling data are generally available for quarterly sampling events between 2005 and 2015, and from October 2019 through March 2021. New biweekly sampling data collected in June and July of 2021 are also included in this evaluation (Arcadis 2021). Sampling data collected prior to the implementation of the Quality Assurance Project Plan (QAPP) in 2005 were not incorporated in this evaluation. Additional water quality data from monitoring station CR0.3, located 0.4 miles upstream of CCAK, were added to the CCAK dataset to provide additional measurements near the USGS gauge. The mercury concentration dataset included only measurements for total (unfiltered) mercury analyzed using EPA Methods 1631 and 1631E.[24] Field duplicates and other quality control samples were excluded from the dataset used to estimate mass loading.

3.3.2 Mass Loading Analysis Approach

Available flow and total mercury data were used to estimate average annual mercury mass loading at monitoring stations in the Crooked Creek watershed under baseline conditions. Mass loading, defined as the total mass of mercury discharged over a period of time, is calculated as the product of mercury concentration and flow, reported in kilograms per year (kg/yr).

3.3.2.1 Estimation of Missing Flow Data

As shown in Figure 3.3-2e for downstream station CCAK, streamflow in Crooked Creek shows strong seasonal patterns, with peak flows associated with spring ice breakup and summer precipitation events and minimum flows in winter following the formation of channel ice (USACE 2018). There is also significant short-term and annual variation in streamflow during the open flow period. Due to this variability, the determination of long-term average mercury mass loading must incorporate daily loading patterns observed over the course of many years. Given the extensive daily flow dataset for CCAK measured by the USGS gauge #15304010, the 14-year period from August 2007 through July 2021 was selected as the averaging period for calculation of average annual mass loading.

For stations upstream of CCAK, flows over the missing winter and early spring periods were estimated to generate a representative daily flow record over the entire averaging period. Plots comparing concurrent flow measurements collected at CCAK and other stations (upper left inset, Figures 3.3-3a through 3.3-3e) demonstrate reasonably strong linear correlations. Linear regression models were fit to the concurrent data records to relate flow at CCAK (Q_{CCAK}) to flow at individual upstream stations (Q_u):

$$Q_u \left(\frac{ft^3}{sec}\right) = slope \times Q_{CCAK} \left(\frac{ft^3}{sec}\right) + intercept$$

The resulting model was applied to estimate the missing flow measurements using the flow data record from CCAK. A small number of negative predicted flows were set to zero.

The inset plots in Figures 3.3-3a to 3.3-3e show the concurrent flow measurements used to fit the regression lines and the resulting flow regression model for each station. At the AMER station, three outliers reflecting flow measurement errors were excluded from the regression analysis.[25] The main plots in Figures 3.3-3a to 3.3-3e show both the observed flow data for the upstream stations, and the estimated upstream flows derived from flow at CCAK. The estimated flows were combined with the

[24] Water quality data in file "Donlin_Hist_All_Flat_08242021.xlsx," provided to Ramboll by Arcadis via email on August 24, 2021.
[25] Flow at AMER is in general highly correlated with flows at the ANDA and CCAK stations. Three outliers at AMER were not correlated with flow at either ANDA or CCAK indicating they were likely affected by measurement error. These outliers were removed from the dataset.

measured flows to create a comprehensive daily flow dataset for each upstream station for the 2007-2021 period.

3.3.2.2 Estimation of Daily Mass Loading

As previously mentioned, reliable mercury sampling data are available for monitoring stations in the Crooked Creek watershed on a quarterly basis for most years after 2005. Previous efforts to model mass loading of various constituents within the Yukon Basin by USGS have applied the USGS LOADEST software program (Runkel et al. 2004) to develop linear regression models that relate daily river flow measurements to mass loading (Striegl et al. 2007; Dornblaser et al. 2009), thereby generating estimates of mercury load on non-sampled dates. A similar approach has been implemented to develop a loading regression model for predicting mercury mass loading in the Crooked Creek drainage area.

For each station, concurrent measurements of streamflow and total mercury concentration were used to calculate instantaneous mercury mass loading in kg/year. For stations other than CCAK, instantaneous loading during frozen periods after 2007 were calculated with estimated flow values. Following the LOADEST method, log-transformed flow at each station (Q_s) was plotted against log-transformed instantaneous loading (L_s) and fit by linear regression:

$$log_{10}(L_s\left(\frac{kg}{yr}\right)) = slope\ \times log_{10}(Q_S\left(\frac{ft^3}{sec}\right)) + intercept$$

Figures 3.3-4a to 3.3-4e show the resulting loading regression models for the five stations in the Crooked Creek watershed.

The coefficients derived from the individual loading regressions were applied to calculate instantaneous mass loading (L_s in kg/y) from daily streamflow (Qs in cfs) for each station by the following equation:

$$L_s = 10^{slope \cdot log_{10}(Q_S) + intercept}$$

3.3.3 Baseline Average Mass Loading

The above equation was applied to the comprehensive daily flow dataset for each station to generate daily estimates of mass loading over the 14-year averaging period. The resulting values were averaged to generate long-term estimates of annual mercury mass loading, shown in Table 3.3-1. Station CCAK, which receives flow from the entire Crooked Creek watershed, was estimated to have a long-term average mercury mass loading of 3.83 kg/year under baseline conditions. Station CCAC, located downstream of approximately 1/3 of the watershed, was estimated to have an average loading of 0.707 kg/year. The remaining stations receive flow from relatively small watersheds and have average loadings ranging from 0.074 – 0.188 kg/year.

Table 3.3-1. Baseline mercury mass loading.

Station	Total Mercury Mass Loading (kg/yr)
DCBO	0.188
AMER	0.074
ANDA	0.105
CCAC	0.707
CCAK	3.83

3.3.4 Mass Balance Under Baseline Conditions

The long-term mercury mass loading values derived above (Table 3.3-1) are inclusive of mercury inputs to surface water from all sources under baseline conditions. The conceptual model for the Crooked Creek watershed recognizes that the origins of mercury in surface water are either geologic (i.e., originating from erosion of mercury-bearing rock) or atmospheric (i.e., originating from background deposition of atmospheric mercury). Thus, the mass balance for a given watershed must balance outflows from the watershed (i.e., mercury mass loading at the drainage point) with inflows (sum of geologic and non-retained atmospheric loading).

Table 3.3-2 presents surface water mercury mass balances for individual stations under baseline conditions. The drainage areas for each station are shown in Figure 3.3-5. Applying the percentage of retained mercury derived in Section 3.1.2, the mercury mass loading to surface water from non-retained background (baseline) atmospheric deposition is estimated as 7% of total baseline air deposition (8.4 µg/m^2-yr; see Section 3.2) applied to the drainage area upstream of each station (Figure 3.3-5). The geologic loading at each station, representing the observed stream loading that is not due to air deposition, was then calculated as the difference between the total loading and the atmospheric loading. The results demonstrate that under baseline conditions mercury mass loading is dominated (71 – 89% of total) by geologic sources of mercury. Examining the mercury mass loading at CCAK, which reflects accumulation of mercury over the entire Crooked Creek watershed, 87% of observed loading originates from geologic sources, with the remaining 13% from background atmospheric deposition. The finding that most mercury mass loading in the Crooked Creek watershed is associated with geologic sources is consistent with the findings of the geochemical fingerprinting source evaluation presented in Section 3.1, which found the mercury in suspended solids in Crooked Creek to be representative of a primarily geologic source.

Table 3.3-2. Baseline mercury mass balance.

Station	Drainage Area (km^2)	Geologic Loading (kg/yr, % of total)	Background Atmospheric Loading (kg/yr, % of total)	Total Mercury Mass Loading (kg/yr)
DCBO	92.1	0.134 (71%)	0.054 (29%)	0.188
AMER	17.75	0.064 (86%)	0.010 (14%)	0.074
ANDA	20.3	0.093 (89%)	0.012 (11%)	0.105
CCAC	292	0.535 (76%)	0.172 (24%)	0.707
CCAK	869	3.32 (87%)	0.511 (13%)	3.83

3.3.5 Mass Balance Under Donlin Project Conditions

The mercury mass balance for surface water in the Crooked Creek watershed will be impacted by the Project in the following ways:

- Project activities will result in additional sources of mercury emissions and atmospheric mercury deposition in the watershed.
- Surface water runoff management and removal of mercury from runoff through water treatment will reduce mercury mass loading from the American Creek and Anaconda Creek watersheds, thereby reducing both geologic and atmospheric mercury mass loading to downstream portions of Crooked Creek. The areas with runoff management are shown in Figure 3.3-6.
- Process and other contact water originating from pit dewatering, the TSF, TSF Seepage Recovery System (SRS) and Contact Water Dams (CWDs) will be treated at a WTP and

discharged to an outfall on Crooked Creek near its confluence with Omega Gulch, as shown on Figure 3.3-6. Although the WTP will treat influent to remove mercury, the WTP effluent may contain trace amounts of mercury.

Other Project activities that may have minor effects on mercury mass loading but were not quantified as part of the mass balance include operation of the Snow Gulch reservoir and groundwater extraction from pit dewatering wells. The Snow Gulch reservoir, designed to provide process makeup water during dry weather periods, would impact mercury mass loading by reducing discharge flow to Crooked Creek and impeding sediment transport above the dam. Given the small size of the Snow Gulch sub-watershed relative to the overall CCAC and CCAK catchment areas, the expected impact would be a small reduction in mercury mass loading to these stations during operation of the Project. As discussed in the FEIS (USACE 2018), dewatering is predicted to reduce streamflow in reaches of Crooked Creek and its tributaries located in proximity to the pit. Streamflow would be most impacted during the winter months, when mercury mass loading is already relatively low, and would result in minor reductions in mercury mass loading to downstream stations CCAC and CCAK.

Table 3.3-3 presents the estimated Project-related atmospheric mercury deposition loading to the five monitoring locations. These were calculated by summing the mercury deposition predicted by deposition modeling within the area upstream of each station that would not be subject to runoff management and after applying the 93% retention rate (as described in Sections 3.1 and 3.2).

Table 3.3-3. Project-related atmospheric mercury loading (kg/year).

Station	Project Atmospheric Loading (kg/yr)
DCBO	0.0015
AMER	0.00017
ANDA	0.0029
CCAC	0.030
CCAK	0.046

Table 3.3-4 presents mercury mass balances for individual monitoring stations under Project conditions. The estimated values shown incorporate Project mercury emissions, implementation of surface water runoff management, and operation of the WTP. These values were calculated as follows:

- In general, Project operations that involve land disturbance (i.e., blasting, waste rock storage, tailings storage) will occur in areas of the site with surface runoff management. Outside these areas, Project activities would generally be subject to permit requirements including implementation of Stormwater Pollution Prevention Plans (SWPPPs) and/or Erosion and Sediment Control Plans (ESCPs) and use of industry standard best management practices (BMPs) for sediment and erosion control (USACE 2018), and thus geologic loading from these areas is not expected to markedly change due to the Project. The geologic loading under Project conditions was calculated by reducing the geologic loading values derived in the baseline mass balance by the proportion of each drainage area that would be subject to surface water runoff management. The percentage of the drainage land area above each station with runoff management is indicated in Table 3.3-2. As shown in Table 3.3-2, nearly all of the American Creek watershed and 51% of the Anaconda Creek watershed will be subject to runoff management under the Project. CCAC and CCAK are downstream of both the American Creek and Anaconda Creek watersheds, plus several adjacent watersheds (Crooked Creek, Lewis Gulch, Omega Creek, Queen Gulch) having small areas subject to runoff management.

- Total atmospheric loading was calculated by summing mercury deposition from both background and Project-related sources. The background loading was calculated using the same atmospheric mercury deposition rate (8.4 $\mu g/m^2$-yr) and retention rate (93%) as in the baseline mass balance, applied to the area upstream of each station not subject to runoff management. The Project-related atmospheric deposition loading is described in Table 3.3-3.
- Mercury mass loading from the WTP outfall on Crooked Creek was estimated using projected flow rates presented in the Water Resources Management Plan (WRMP; SRK Consulting 2017). The operations water balance for Project years 2 to 27 under the above average precipitation case indicates an average annual outflow of 1,378 gallons per minute (gpm) from the WTP. Although predicted effluent mercury concentrations are not presented in the WRMP, Table 4-6 of the WRMP indicates the 95th percentile mercury concentration in WTP effluent will not exceed the AWQS for mercury of 12 ng/L. Using the AWQS as a worst-case concentration and the average outflow results in a conservative estimate of mercury mass loading at the outfall of 0.033 kg/year. This loading is applied to the mass balances at CCAC and CCAK, which are downstream of the outfall.

Table 3.3-4. Project conditions mercury mass balance.

Station	Runoff Management (km^2, % of Drainage Area)	Loading During Project (kg/yr)					Change in Total Loading from Baseline (%)
		Geogenic	Atmospheric (Background)	Atmospheric (Project)	WTP Outfall	Total	
DCBO	0 (0%)	0.134	0.054	0.0015	-	0.190	0.8%
AMER	17.69 (99.7%)	0.00020	0.00003	0.00017	-	0.00040	-99.5%
ANDA	10.5 (52%)	0.045	0.0057	0.0029	-	0.054	-49.0%
CCAC	32 (11%)	0.477	0.153	0.030	0.033	0.693	-2.0%
CCAK	32 (3.7%)	3.20	0.492	0.046	0.033	3.77	-1.6%

Numbers may not add exactly due to rounding.

Figure 3.3-7 illustrates the differences between the baseline and project conditions mercury mass balances for stations DCBO, AMER and ANDA. Corresponding diagrams are shown in Figure 3.3-8 for CCAC and CCAK. In the Donlin Creek watershed that drains into station DCBO, only a very small increase (less than 1 percent) in mercury mass loading is associated with the Project. In the American and Anaconda Creek watersheds that drain into stations AMER and ANDA, there is a significant reduction in mercury mass loading because the amount of mercury removed by the Project's treatment of surface water runoff is much higher than the increase in loading from the Project atmospheric deposition of mercury.

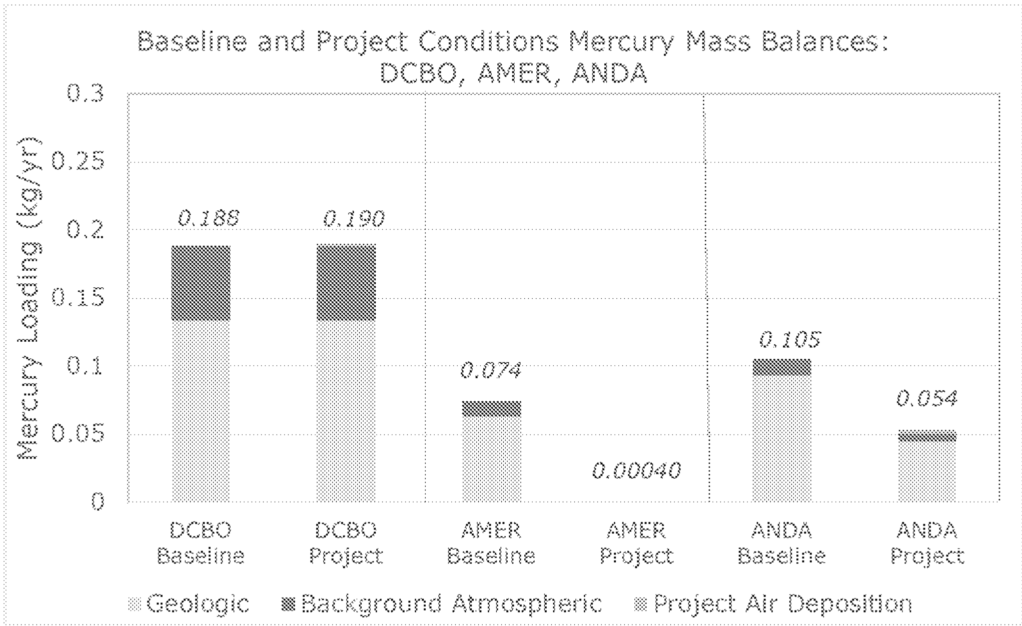


Figure 3.3-7. Comparison of baseline and project conditions mass balances (DCBO, AMER, ANDA).

The reductions in loading within American and Anaconda Creeks due to runoff management also reduce loading in the downstream Crooked Creek watersheds drained by stations CCAC and CCAK. This reduction in loading due to runoff management in the watersheds drained by CCAC and CCAK is greater than increases in loading due to atmospheric deposition and treated wastewater discharge from the outfall. Over the entire Crooked Creek watershed, the Project is estimated to reduce the long-term average mercury mass loading in surface water by 1.6%.

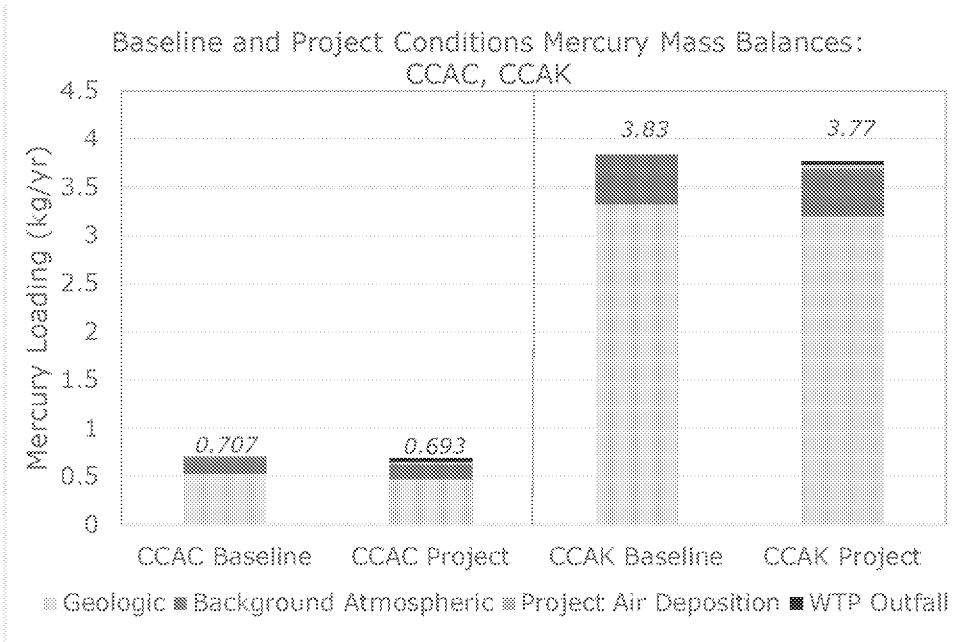


Figure 3.3-8. Comparison of baseline and project conditions mercury mass balances (CCAC, CCAK).

The figures for Section 3.3 (except for Figures 3.3-7 and 3.3-8) are shown in the attachment titled "Appendix A".

3.4 Mercury Concentrations in the Streams

As described in section 3.3, the long-term average mercury mass loading at five stations within the Crooked Creek watershed was estimated to stay roughly the same or decrease due to Project activities. As mercury mass loading is the product of flow and mercury concentration, a reduction in average loading from baseline conditions will also result in a reduction in mercury concentrations, assuming that streamflow is unaffected by the Project. However, where the surface water flow also changes due to the Project, additional analysis is needed to determine the effect on concentrations. In this section, the potential impacts of the Project on mercury concentrations in surface water are evaluated for different locations within the Crooked Creek watershed.

3.4.1 Near-Project and Downstream Mercury Concentrations

As described in the FEIS, surface water flows near the mine will be reduced due to the diversion of surface water runoff and the reduction in groundwater seepage to surface water due to pit dewatering. Although some of this water will be treated and discharged back to Crooked Creek, a portion of the water will be consumed as part of mine operations. The reduction in streamflow due to the Project was quantified for American Creek, Anaconda Creek, and different points in Crooked Creek in the FEIS under four scenarios (see Table 3.5-26, FEIS). In this analysis, there were no streams in which streamflow was predicted to increase during the Project as compared to baseline conditions. The correlations between historical mercury concentrations and streamflow at ANDA, AMER, CCAC and CCAK stations are shown in Figure 3.4-1 (see Appendix A). In all cases, a statistically significant positive correlation is observed, indicating that higher flows are associated with higher mercury concentrations, and lower flows are associated with lower mercury concentrations.

The FEIS noted similar positive correlations between streamflow and mercury concentrations at stations CCAC and CCAK. The FEIS also references an evaluation of mercury concentrations under different streamflow conditions (i.e., base flow, spring flow, and storm flow), which found generally higher mercury concentrations during spring and storm flow conditions relative to base flow. The FEIS notes that higher stream discharge is usually associated with higher flow velocity, which entrains particulate matter from the stream bed during high flow events, and that a substantial fraction of the total mercury load in the Crooked Creek watershed is associated with these high flow events. This finding is supported by Arcadis (2020), which found total mercury concentrations in Crooked Creek above the AWQS to be the result of mercury associated with suspended particles mobilized during high flow events, based on observed correlations between mercury and total suspended solids concentrations. This linkage between flow velocity and particle suspension provides a physical basis for the observed correlation between streamflow and mercury concentration.

Although the correlations between streamflow and mercury concentration shown in Figure 3.4-1 were evaluated under baseline conditions, this relationship would still hold under Project conditions, since both the mass balance and geochemical fingerprinting evaluations found atmospheric deposition to be a relatively minor contribution to mercury mass loading in Crooked Creek relative to geologic sources. Based on these results, the reduction in streamflow resulting from Project water use would be associated with a decrease in average mercury concentrations in surface water at ANDA, AMER, CCAC and CCAK. Since the mine water management and dewatering systems would be operating throughout the life of the Project, the expected the reductions in streamflow, and hence mercury concentrations, would be consistent over time.

3.4.2 Upstream Mercury Concentrations

At DCBO, located on Donlin Creek upstream of the Project, streamflow is not expected to change due to the Project. However, the mercury mass balance under Project conditions predicts a small increase in mercury mass loading at DCBO due to Project mercury air deposition in the watershed. To quantify the impact on mercury concentrations at DCBO, the same percentage increase in mercury mass loading predicted at DCBO (0.80%) was applied to historical mercury concentrations measured at DCBO to determine the effect of this increase on the likelihood of concentrations being higher than 12 ng/L (the mercury AWQS). Of the 62 water quality samples collected at DCBO between 2003 and 2021, only six samples (9.7%) contained mercury concentrations above 12 ng/L. After applying the assumed 0.80% concentration increase to all the baseline measurements at DCBO, there was no change in the number of samples with mercury concentrations above 12 ng/L. Thus, the Project would have a negligible impact on mercury water quality in the DCBO watershed. Similarly, negligible mercury water quality impacts would be expected in other watersheds, both within and outside the Crooked Creek watershed, where very small increases in mass loadings are predicted and the Project would not impact streamflows. This is especially the case as the distance from the Project increases and the amount of Project-related deposition is minimal.

4 REFERENCES

Air Sciences, 2021. PSD Construction Permit Application Report. Donlin Gold Project, Alaska. Prepared for Donlin Gold LLC. October 18.

Arcadis, 2007. Baseline Mercury in Vegetation, Soil, and Steam Sediment, Donlin Creek Project, Alaska. Prepared for Barrick gold Corporation. March.

Arcadis. 2014. Assessment of Mercury Fate in the Environment from Changes in Atmospheric Deposition. Prepared for Donlin Gold, LLC.

Arcadis. 2020. Evaluation of Historical Mercury Dynamics in Surface Water, Donlin Gold Project, Western Alaska. December 4.

Arcadis, 2021. Donlin Gold Mine Mercury Dynamics Evaluation. 2021 Draft Field Implementation Report. Prepared for Donlin Gold. October.

Bergametti, G., Marticorena, B., Rajot, J. L., Foret, G., Alfaro, S. C., & Laurent, B. 2018. Size-resolved dry deposition velocities of dust particles: In situ measurements and parameterizations testing. Journal of Geophysical Research: Atmospheres, 123, 11,080– 11,099. https://doi.org/10.1029/2018JD028964.

Brigham, M. E., Wentz, D. A., Aiken, G. R., and Krabbenhoft, D. P. 2009. Mercury cycling in stream ecosystems. 1. Water column chemistry and transport. Environ. Sci. Technol. 43, 2720–2725. doi:10.1021/es802694n.

Chen, C.-W., Kao, C.-M., Chen, C.-F., and Dong, C.-D. 2007. Distribution and accumulation of heavy metals in the sediments of Kaohsiung Harbor, Taiwan. *Chemosphere* 66: 1431-1440.

Commission for Environmental Cooperation (CEC). 1997. Ecological regions of North America: toward a common perspective.

Demers, J. D., Driscoll, C. T., and Shanley, J. B. 2010. Mercury mobilization and episodic stream acidification during snowmelt: Role of hydrologic flow paths, source areas, and supply of dissolved organic carbon. *Water Resour. Res.* 46. doi:10.1029/2008wr007021.

Dommergue, A., Ferrari, C. P., Gauchard, P. A., Boutron, C. F., Poissant, L., Pilote, M., et al. 2003. The fate of mercury species in a sub-arctic snowpack during snowmelt. *Geophys. Res. Lett.* 30, 12–15. doi:10.1029/2003GL017308.

Donlin. 2014. "Updated Metals Information for Ore and Wasterock."*File: Donlin ICP Analyses in pit with ore and waste 20140903-mr.xlsx.* Email from M. Rieser, Donlin Gold LLC, to E. Memon, Air Sciecnes Inc., September 3.

Donlin Gold. 2015. Tailings Beach Revision. File: Tables-from_PM-0011186.0071_Updated-Beach-and-Pond-Areas.pdf, BGC Engineering Inc. Email from M. Rieser, Donlin Gold LLC, to K. Lewis, Air Sciences Inc., June 22.

Dornblaser, M. M., and R. G. Striegl. 2009. Suspended sediment and carbonate transport in the Yukon River Basin, Alaska: Fluxes and potential future responses to climate change, Water Resour. Res., 45, W06411, doi:10.1029/2008WR007546.

Drevnick, P. E., Cooke, C. A., Barraza, D., Blais, J. M., Coale, K. H., Cumming, B. F., et al. 2016. Spatiotemporal patterns of mercury accumulation in lake sediments of western North America. *Sci. Total Environ.* 568, 1157–1170. doi:10.1016/j.scitotenv.2016.03.167.

Eckley CS, Gustin M, Miller MB, Marsik F., 2011a. Scaling nonpoint source Hg emissions from active industrial gold mines – influential variables and annual emission estimates. Env Sci Tech 2011;45:392-399.

Eckley CS, Gustin M, Miller MB, Marsik F., 2011b. Measurement of surface mercury fluxes at active industrial gold mines in Nevada (USA). Sci Total Environ 2011;409:514–522.

Emerson, E. W., Hodshire, A. L., DeBolt, H. M., Bilsback, K. R, Pierce, J. R., McMeeking, G. R., and Farmer, D. K. 2020. Revisiting particle dry deposition and its role in radiative effect estimates. Proceedings of the National Academy of Sciences, 117(42), 26076-26082. https://doi.org/10.1073/pnas.2014761117.

ENVIRON, 2013. Monitoring of baseline air concentrations and deposition of mercury for the Donlin Gold Project. Report prepared for Donlin Gold, December 2013, Novato, CA.

ENVIRON, 2015. Modeling of local impacts of mercury air emissions from stacks and fugitive sources, advanced water treatment scenario: Donlin Gold Mine, Alaska. Report prepared for Donlin Gold, September 2015, Novato, CA.

Grigal, D. F. 2002. Inputs and outputs of mercury from terrestrial watersheds: A review. *Environ. Rev.* 10, 1–39. doi:10.1139/a01-013.

Guérdon, S., Grangeon, S., Jouravel, G., Charlet, L., and Sarret, G. 2013. Atmospheric mercury incorporation in soils of an area impacted by a chlor-alkali plant (Grenoble, France): Contribution of canopy uptake. *Sci Total Environ* 446: 356-364.

Harris, R. C., Rudd, J. W. M., Amyot, M., Babiarz, C. L., Beaty, K. G., Blanchfield, P. J., et al. 2007. Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. *Proc. Natl. Acad. Sci. U. S. A.* 104, 16586–16591. doi:10.1073/pnas.0704186104.

Hatch. 2014. Donlin Gold Mercury Emissions Controls Summary. H330800-17-00-236-0002, Rev. 1. Hatch, May 27.

Haynes, K. M., and Mitchell, C. P. J. 2012. Inter-annual and spatial variability in hillslope runoff and mercury flux during spring snowmelt. *J. Environ. Monit.* 14, 2083–2091. doi:10.1039/c2em30267e.

Hintelmann, H., Harris, R., Heyes, A., Hurley, J. P., Kelly, C. A., Krabbenhoft, D. P., et al. 2002. Reactivity and mobility of new and old mercury deposition in a boreal forest ecosystem during the first year of the METAALICUS study. *Environ. Sci. Technol.* 36, 5034–5040. doi:10.1021/es025572t.

Hissler, C., and Probst, J.-L. 2006. Impact of mercury atmospheric deposition on soils and streams in a mountainous catchment (Vosges, France) polluted by chlor-alkali industrial activity: the important trapping role of the organic matter. *Sci Total Environ* 361: 163-178.

Jiskra, M., Wiederhold, J. G., Skyllberg, U., Kronberg, R. M., Hajdas, I., and Kretzschmar, R. 2015. Mercury Deposition and Re-emission Pathways in Boreal Forest Soils Investigated with Hg Isotope Signatures. *Environ. Sci. Technol.* 49, 7188–7196. doi:10.1021/acs.est.5b00742.

Kamman, N. C., and Engstrom, D. R. 2002. Historical and present fluxes of mercury to Vermont and New Hampshire lakes inferred from 210Pb dated sediment cores. *Atmos. Environ.* 36, 1599–1609. doi:10.1016/S1352-2310(02)00091-2.

Malone, K. 1962. Mercury occurrences in Alaska. U.S. Department of the Interior, Bureau of Mines.

NDEP (Nevada Department of Environmental Protection). 2016. Nevada Mercury Control Program Permitting Guidance, General Industry NvMACT Determinations. Nevada Division of Environmental Protection (NDEP) Bureau of Air Pollution Control, February 29.

Obrist, D., Agnan, Y., Jiskra, M., Olson, C. L., Colegrove, D. P., Hueber, J., et al. 2017. Tundra uptake of atmospheric elemental mercury drives Arctic mercury pollution. *Nature* 547, 201–204. doi:10.1038/nature22997.

Obrist, D., Kirk, J. L., Zhang, L., Sunderland, E. M., Jiskra, M., and Selin, N. E. 2018. A review of global environmental mercury processes in response to human and natural perturbations: Changes of emissions, climate, and land use. *Ambio* 47, 116–140. doi:10.1007/s13280-017-1004-9.

Oswald, C. J., Heyes, A., and Branfireun, B. A. 2014. Fate and transport of ambient mercury and applied mercury isotope in terrestrial upland soils: Insights from the METAALICUS watershed. *Environ. Sci. Technol.* 48, 1023–1031. doi:10.1021/es404260f.

Runkel, R. L., C. G. Crawford, and T. A. Cohn. 2004, Load Estimator (LOADEST): A FORTRAN program for estimating constituent loads in streams and rivers, U.S. Geol. Surv. Techniques Methods, Book 4, Chap. A5, 69 pp.

Seinfeld and Pandis. 2016. Atmospheric Chemistry and Physics. From Air Pollution to Climate Change. 3rd Edition. Wiley.

Selin, N. E. 2009. Global biogeochemical cycling of mercury: A review. *Annu. Rev. Environ. Resour.* 34, 43–63. doi:10.1146/annurev.environ.051308.084314.

Siqueira, G.W., Aprile, F., Irion, G., and Braga, E.S. 2018. Mercury in the Amazon basin: Human influence of natural geological pattern? *Journal of South American Earth Sciences* 86: 193-199.

Smith-Downey, N. V., Sunderland, E. M., and Jacob, D. J. 2010. Anthropogenic impacts on global storage and emissions of mercury from terrestrial soils: Insights from a new global model. *J. Geophys. Res. Biogeosciences* 115, 1–11. doi:10.1029/2009JG001124.

SRK (SRK Consulting), 2011. Metal Leaching and Acid Rock Drainage Assessment Donlin Creek Project, Alaska Update Report. Report prepared for Donlin Gold LLC. February.

SRK, 2012. Water Resources Management Plan: Plan of Operations-Volume II. Prepared for Donlin Gold, July 2012.

SRK, 2017. Water Resources Management Plan: Plan of Operations. Prepared for Donlin Gold, February 2017.

St. Louis, V. L., Rudd, J., Kelly, C., Beaty, K., Flett, R., and Roulet, N. 1996. Production and Loss of Methylmercury and Loss of Total Mercury from Boreal Forest Catchments Containing Different Types of Wetlands†. Environmental Science & Technology - Environ Sci Technol, 30. 10.1021/es950856h.

St. Louis, V. L., Graydon, J. A., Mitchell, C., Oswald, C., Arp, P., Branfireun, B., et al. 2016. "Chapter 5: Mercury Fate and Methylation in Terrestrial Upland and Wetland Environments," in *Canadian Mercury Science Assessment*, 229–284.

Striegl, R. G., M. M. Dornblaser, G. R. Aiken, K. P. Wickland, and P. A. Raymond. 2007. Carbon export and cycling by the Yukon, Tanana, and Porcupine rivers, Alaska, 2001–2005, Water Resour. Res., 43, W02411, doi:10.1029/2006WR005201.

Swain, E. B., Engstrom, D. R., Brigham, M. E., Henning, T. A., and Brezonik, P. L. 1992. Increasing rates of atmospheric mercury deposition in midcontinental North America. *Science.* 257, 784–787. doi:10.1126/science.257.5071.784.

U.S. Army Corps of Engineers & U.S. Bureau of Land Management, Donlin Gold Project Joint Record of Decision and Permit Evaluation (ROD), DEC 002671.

United States Army Corps of Engineers (USACE). 2018. Donlin Gold Project; Final Environmental Impact Statement. April.

W. R. Reed, "Significant Dust Dispersion Models for Mining Operations", CDC Information Circular 9478, September 2005.

Wang, X., Zhang, L., and Moran, M. D. 2010. Uncertainty assessment of current size-resolved parameterizations for below-cloud particle scavenging by rain, Atmos. Chem. Phys., 10, 5685–5705. https://doi.org/10.5194/acp-10-5685-2010.

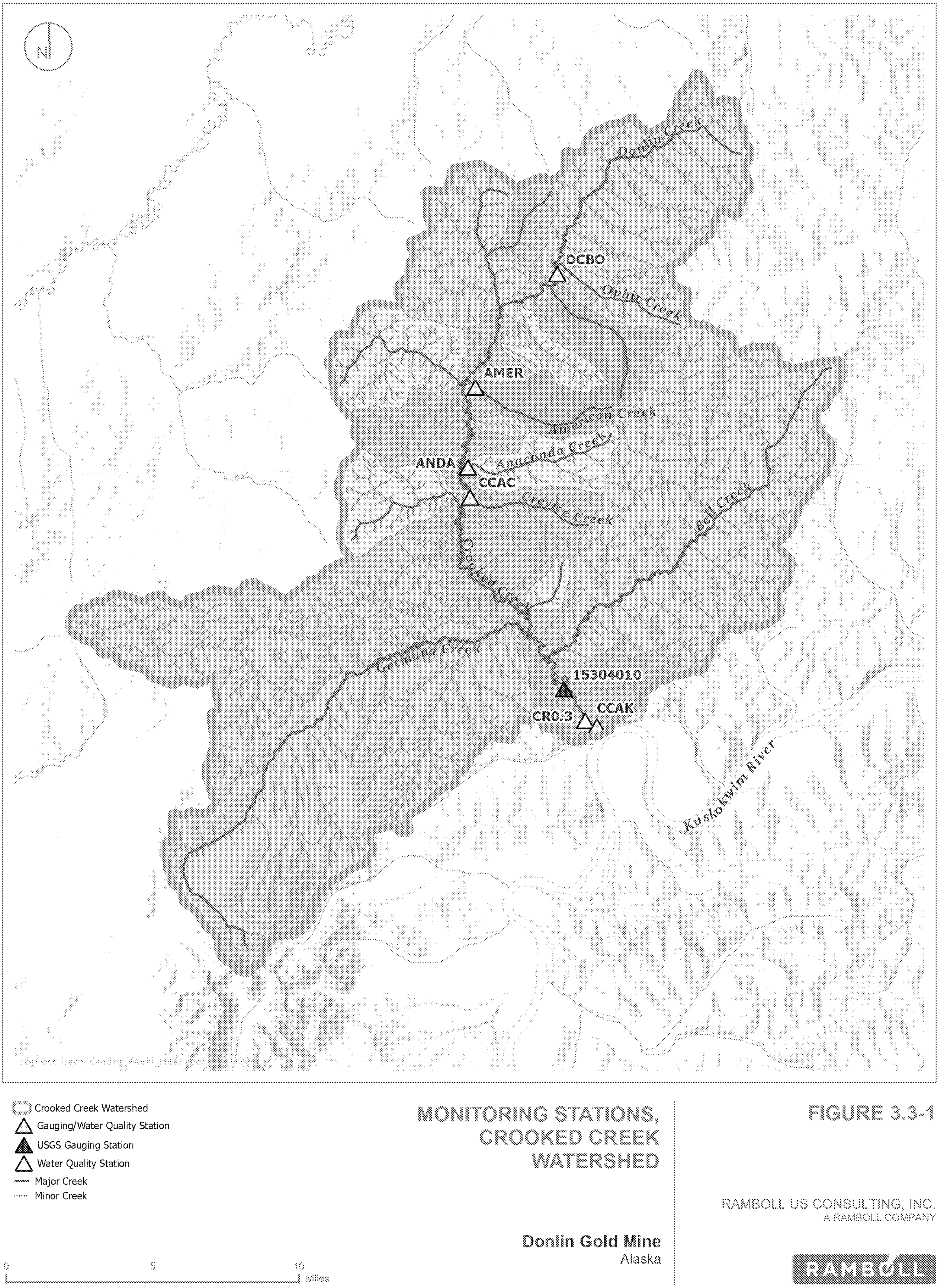
Wang, X., Zhang, L., and Moran, M. D. 2014. Bulk or modal parameterizations for below-cloud scavenging of fine, coarse, and giant particles by both rain and snow, J Adv Model Earth Syst, 6, 1301–1310, doi:10.1002/2014MS000392.

APPENDIX A

Figures for Sections 3.3 and 3.4

PROJECT: 1690022020 | DATED: 10/1/2021 | DESIGNER: LACKERMAN

C:\Users\lackerman\Ramboll\Donlin - General\work\water team\report\Section_3_3_Figures.aprx



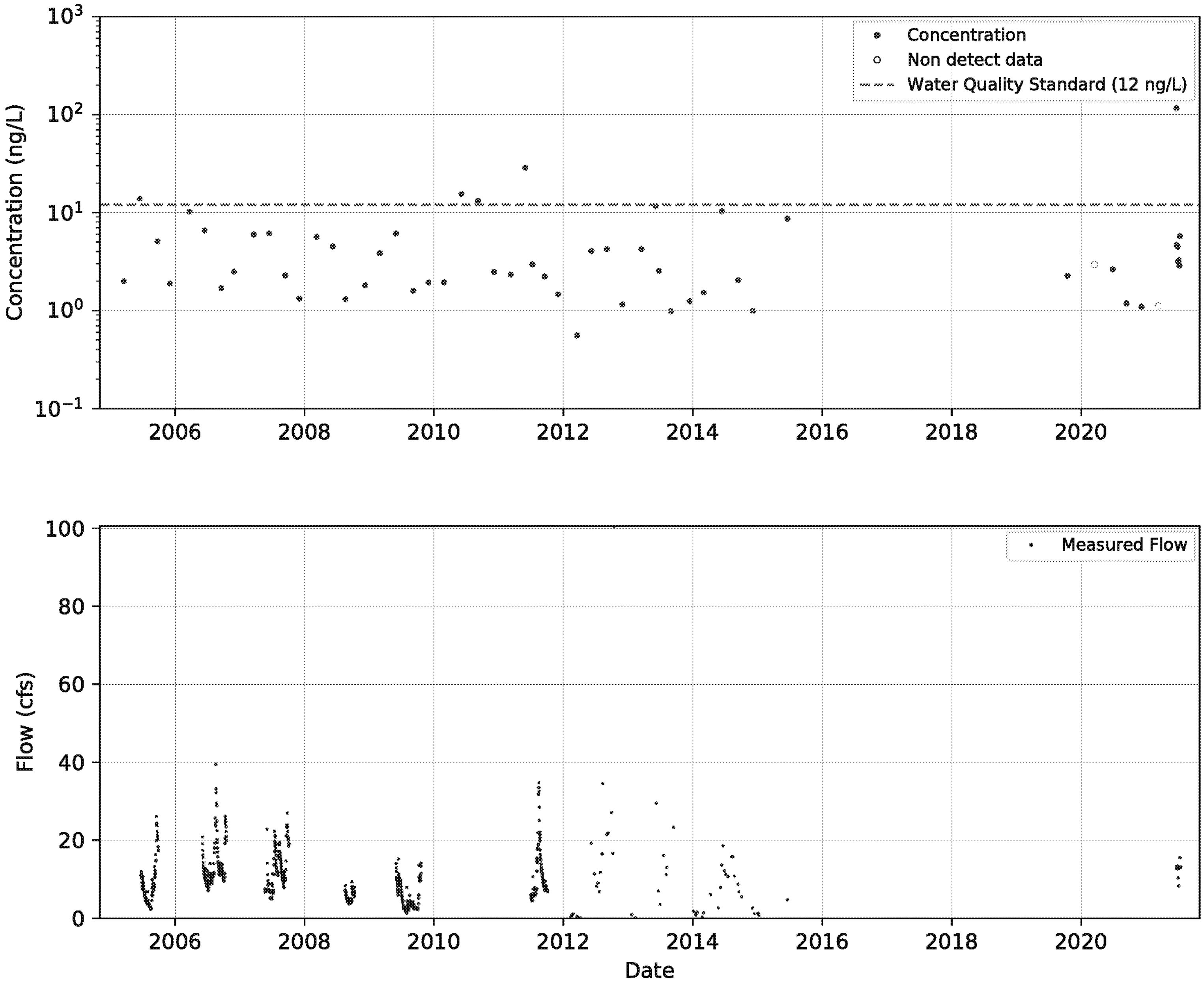
MONITORING STATIONS, CROOKED CREEK WATERSHED

Donlin Gold Mine
Alaska

FIGURE 3.3-1

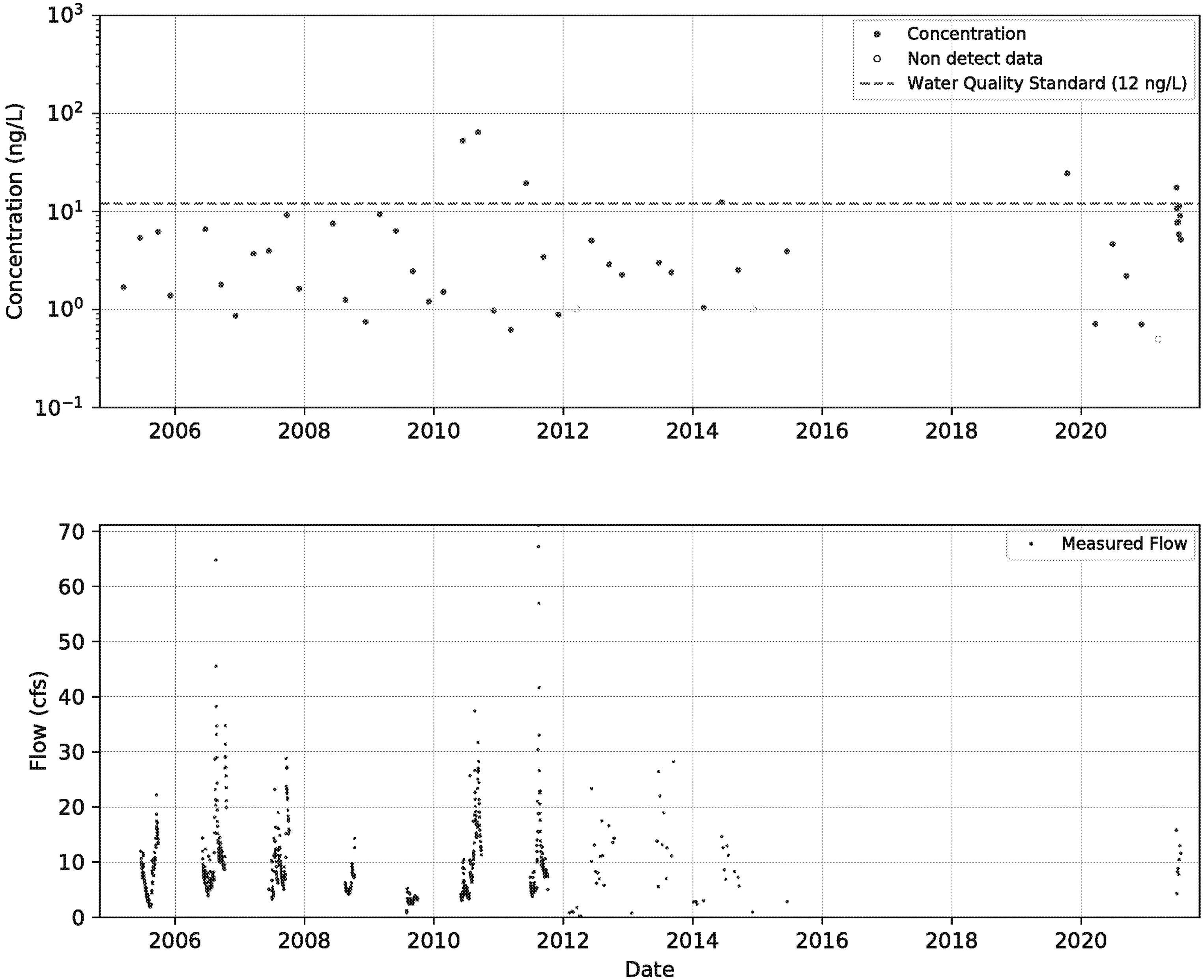
RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py



RAMBOLL	**Measured Flow and Mercury Concentration - AMER** Donlin Gold Project Crooked Creek, Alaska	Figure **3.3-2a**
	Drafter: PR Date: 10/01/21 Contract Number: 1690022020	

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py



RAMBOLL

Measured Flow and Mercury Concentration - ANDA
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-2b

Drafter: PR Date: 10/01/21 Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py

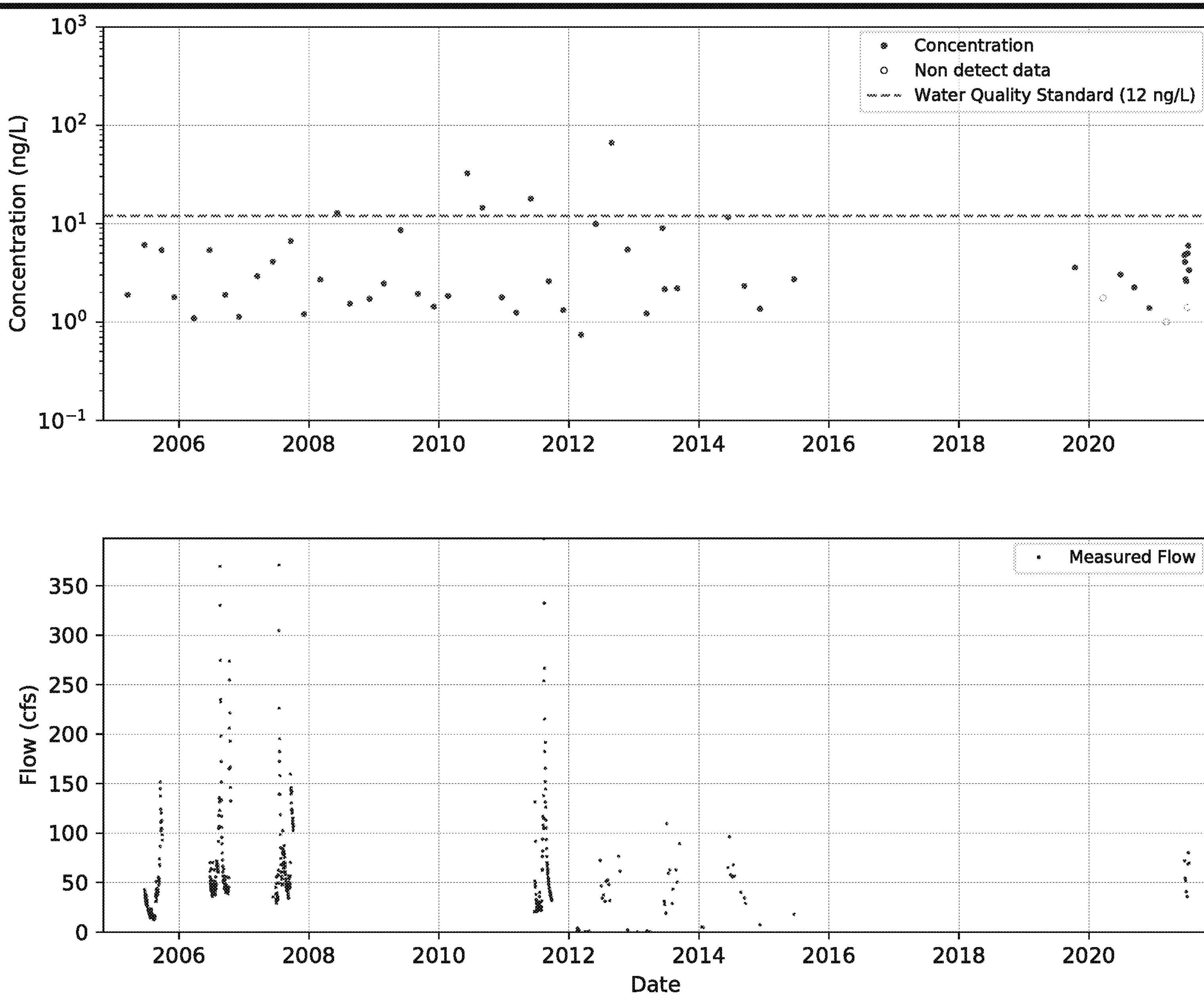
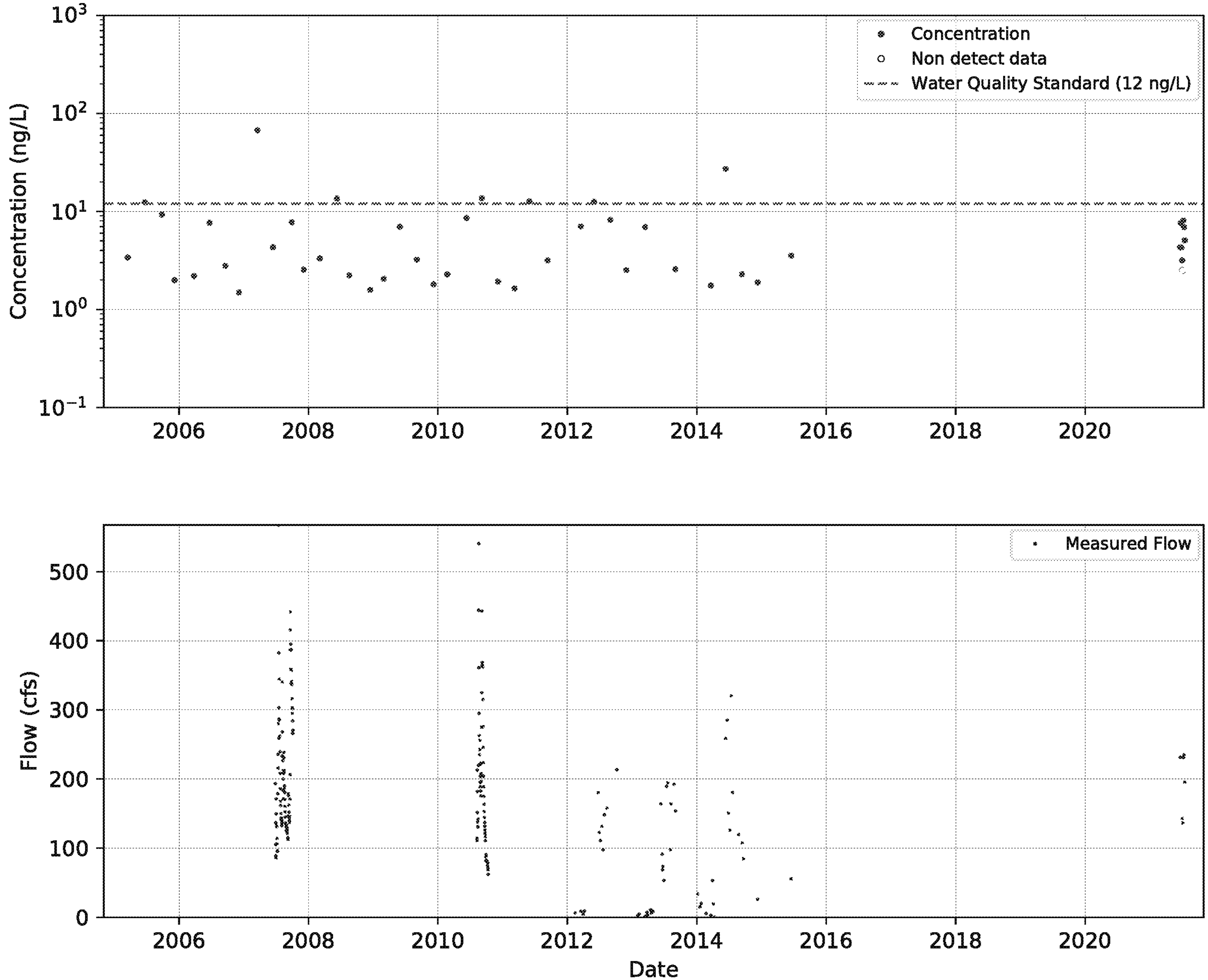


		Figure
RAMBOLL	**Measured Flow and Mercury Concentration - DCBO** Donlin Gold Project Crooked Creek, Alaska	**3.3-2c**
	Drafter: PR Date: 10/01/21 Contract Number: 1690022020	



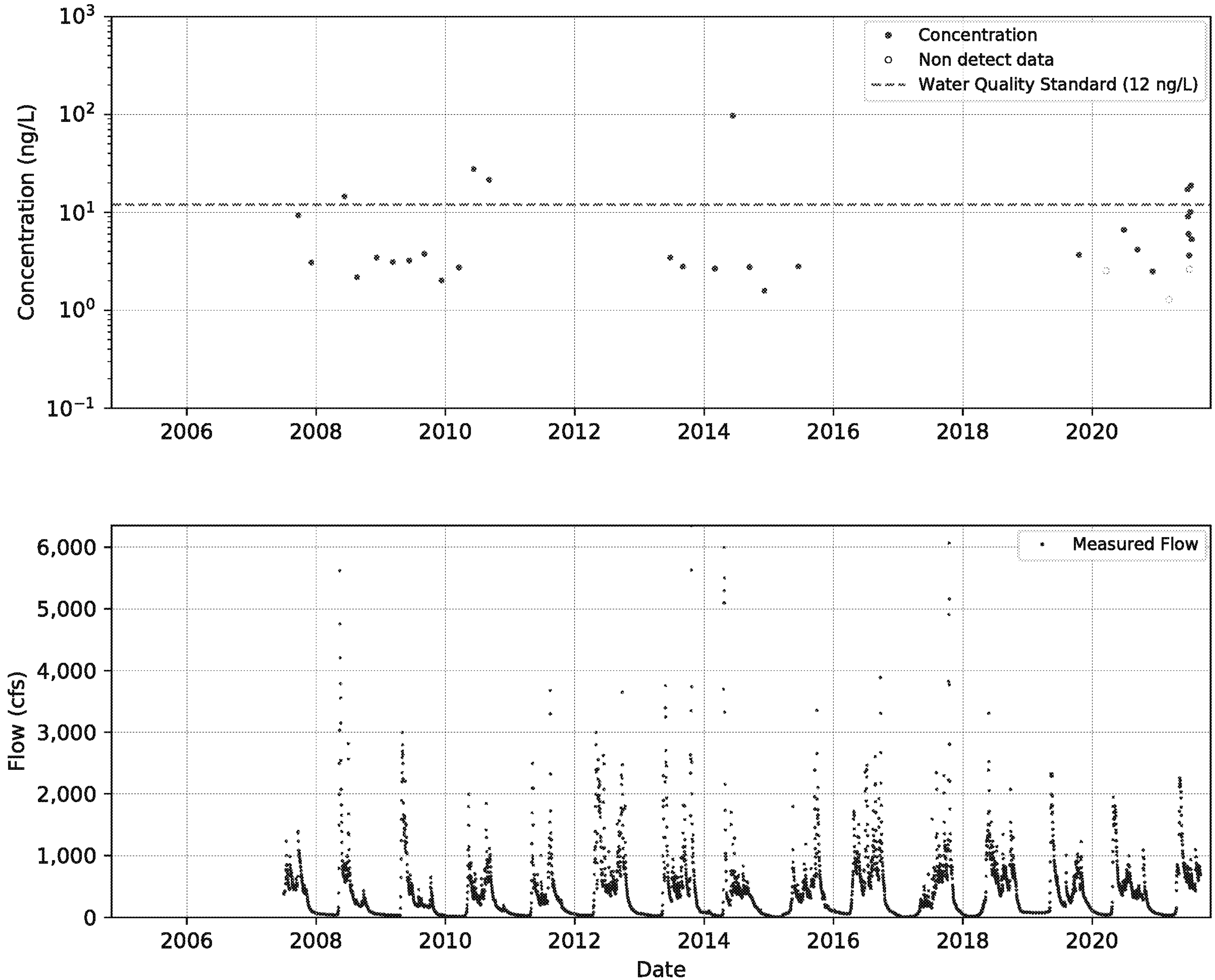
RAMBOLL

Measured Flow and Mercury Concentration - CCAC
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-2d

Drafter: PR | Date: 10/01/21 | Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py

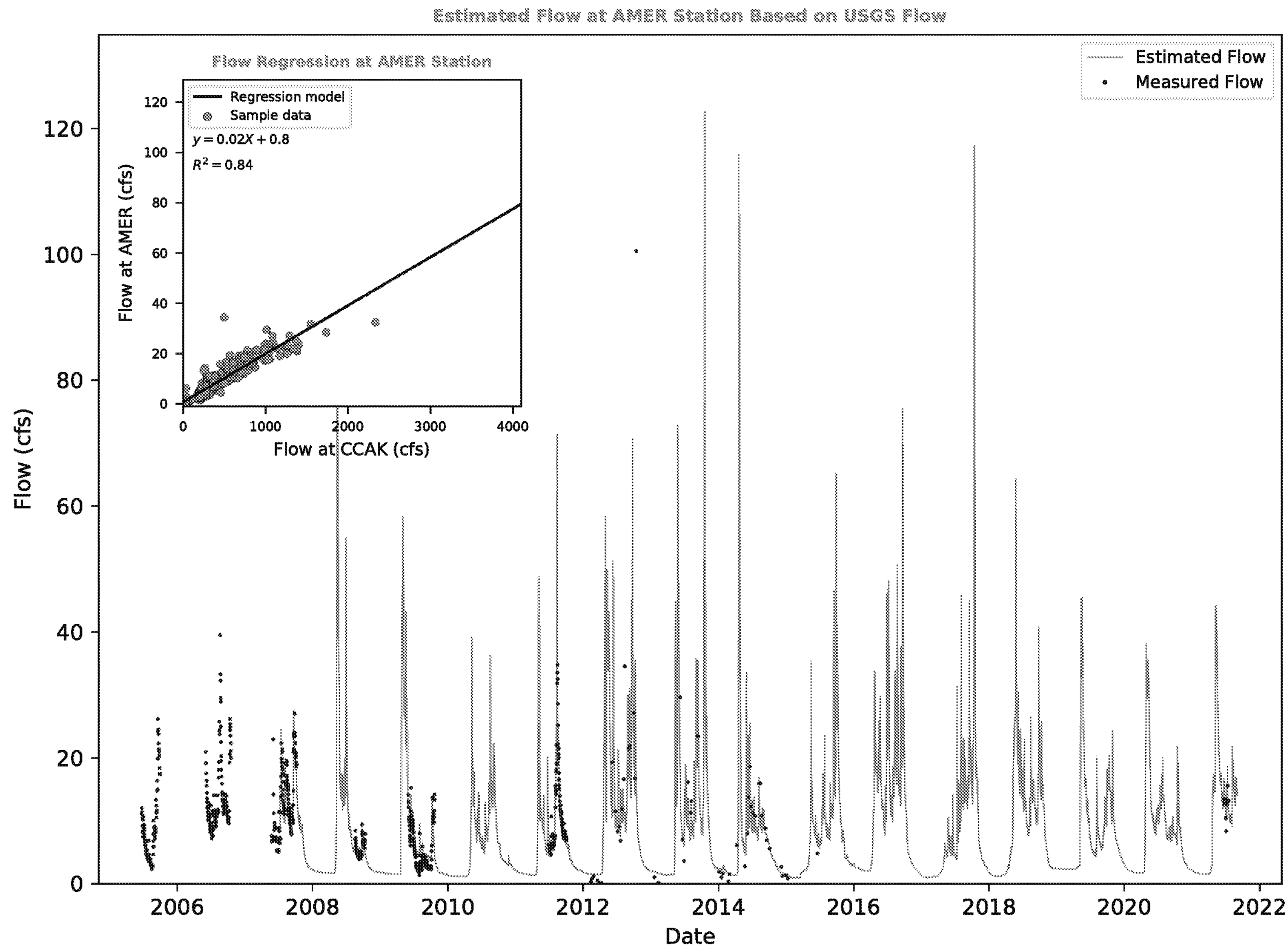


RAMBOLL

Measured Flow and Mercury Concentration - CCAK
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-2e

Drafter: PR | Date: 10/01/21 | Contract Number: 1690022020

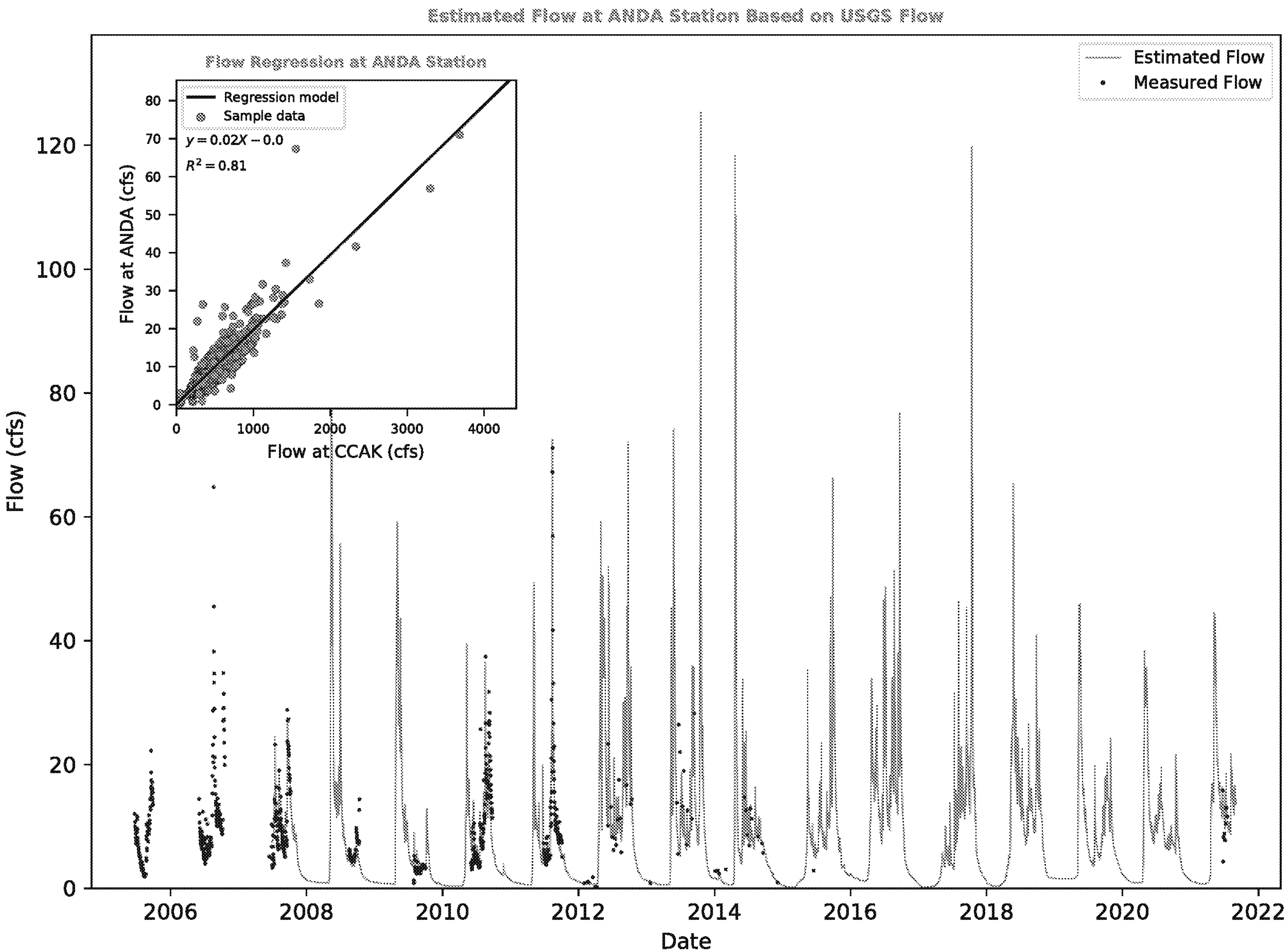


Flow Regression at AMER Station
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-3a

Drafter: PR | Date: 10/01/21 | Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py

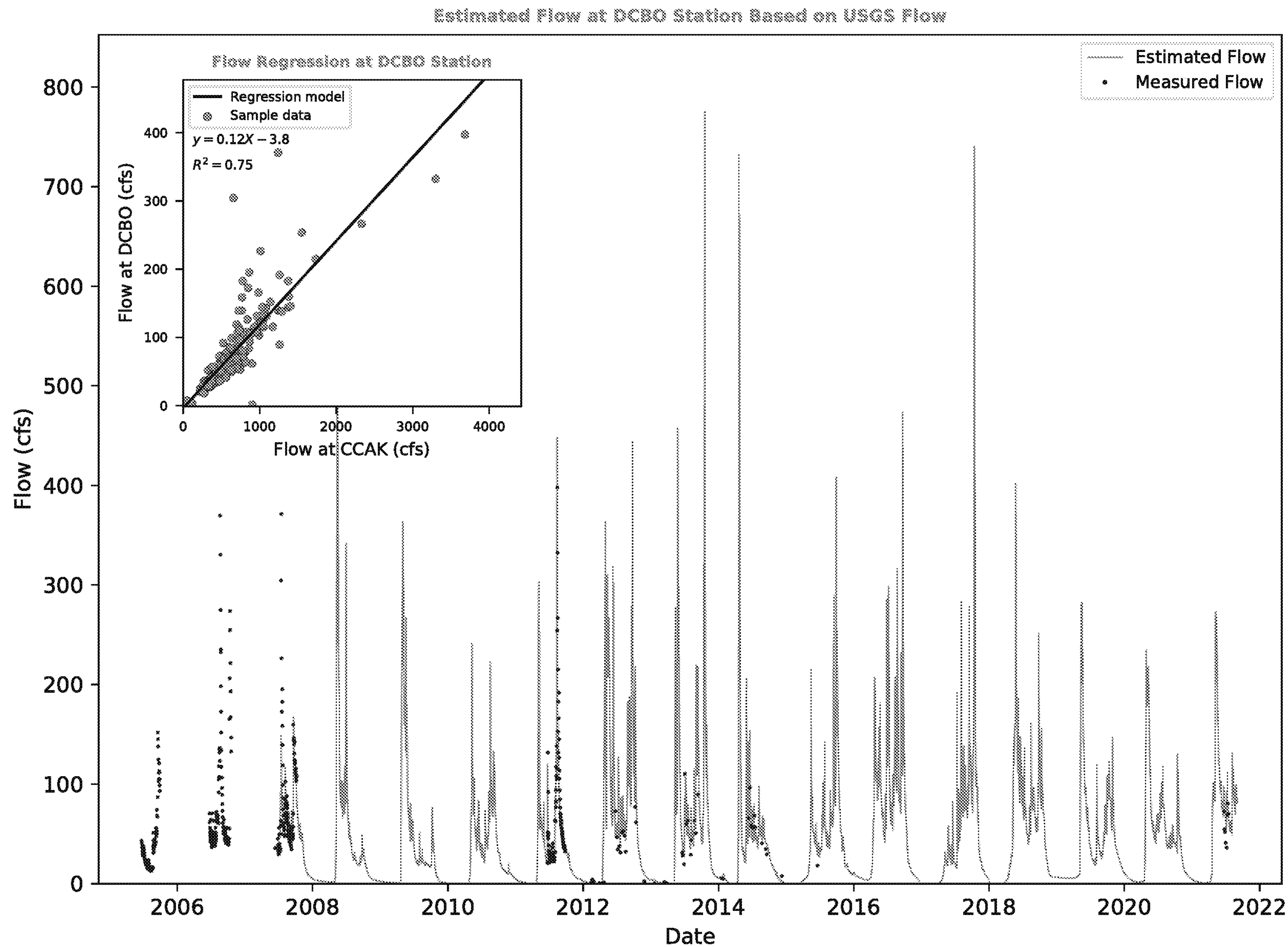


Flow Regression at ANDA Station
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-3b

Drafter: PR Date: 10/01/21 Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py

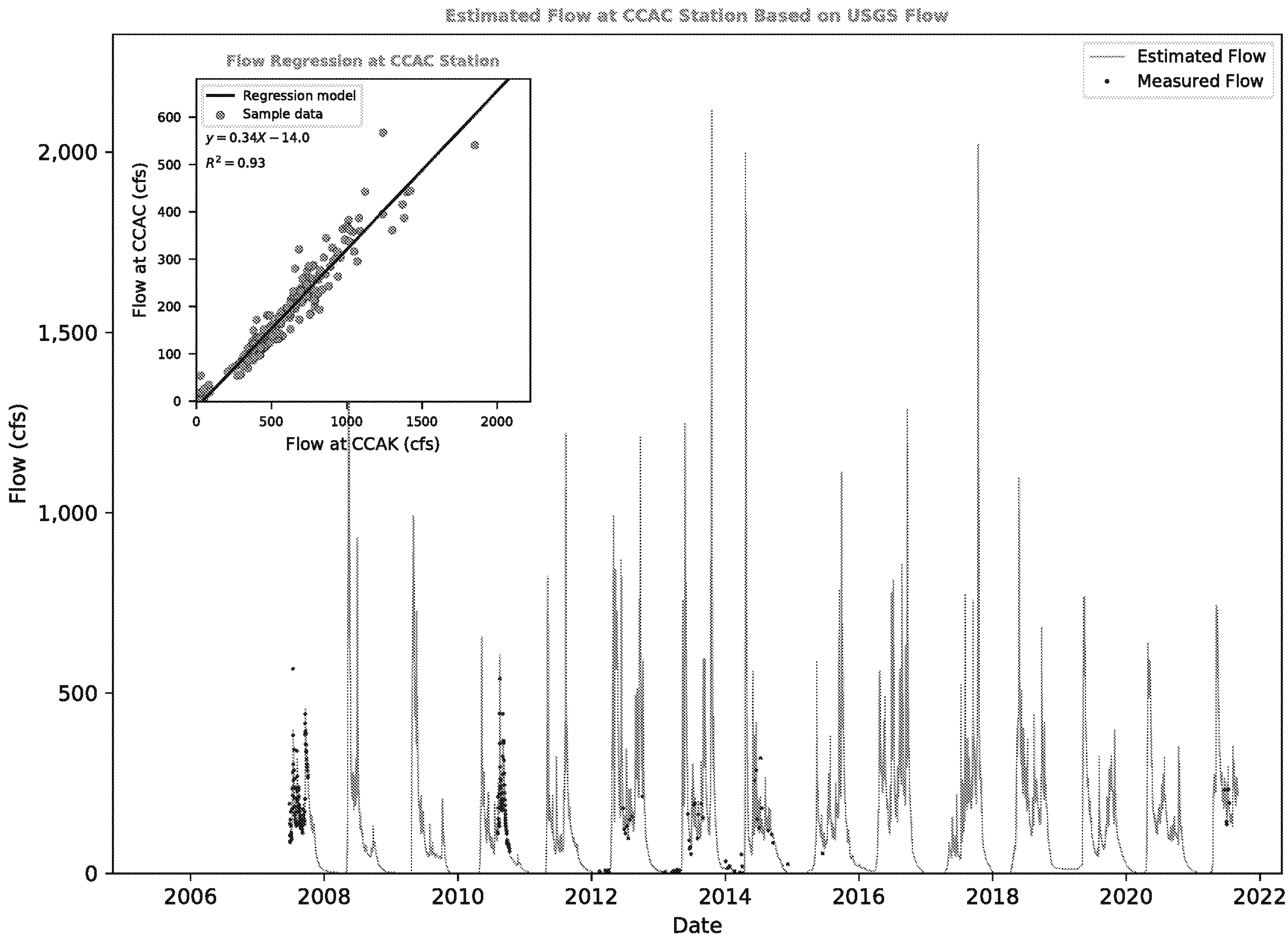


RAMBOLL

Flow Regression at DCBO Station
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-3c

Drafter: PR Date: 10/01/21 Contract Number: 1690022020



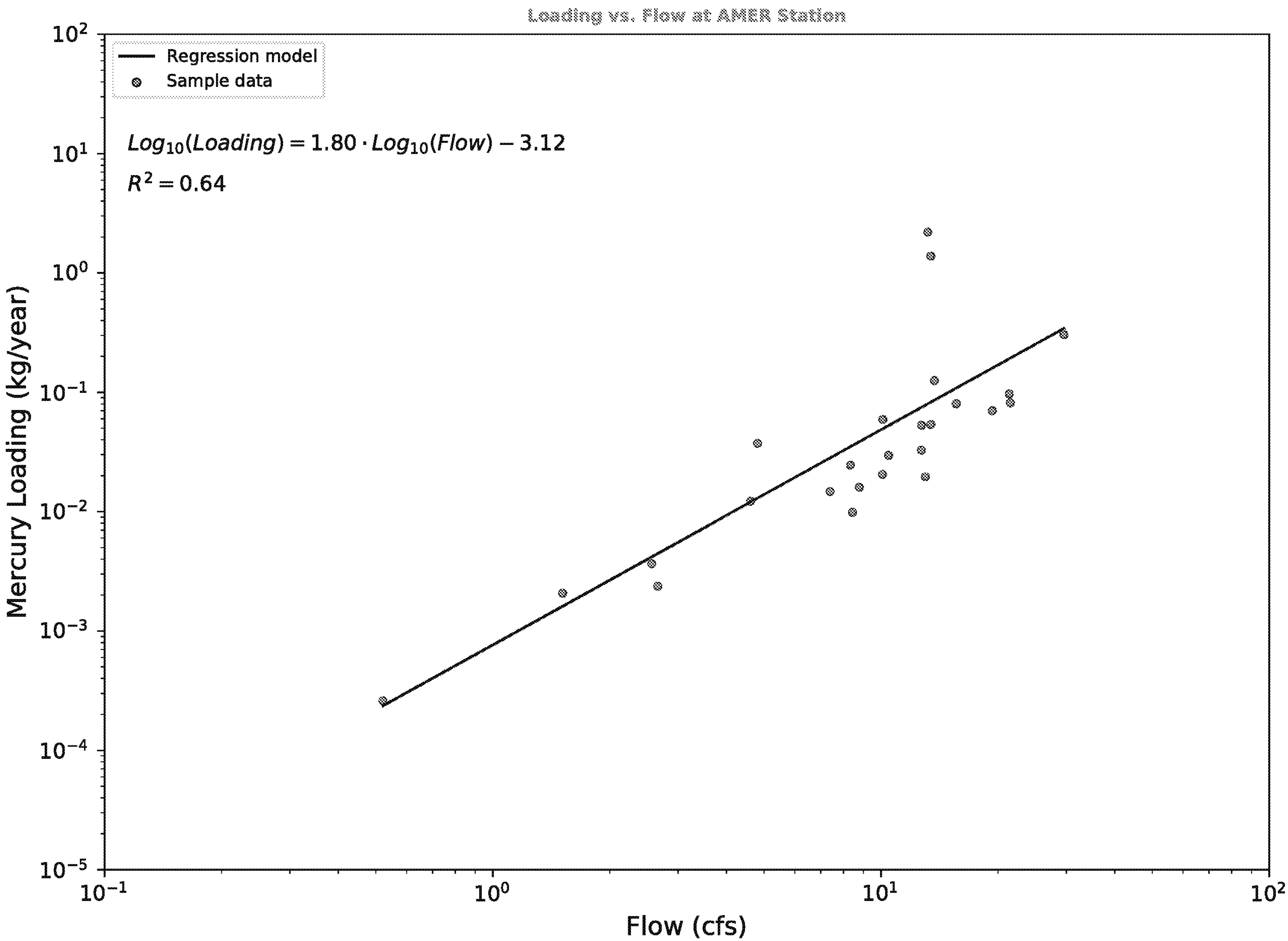
RAMBOLL

Flow Regression at CCAC Station
Donlin Gold Project
Crooked Creek, Alaska

Figure

3.3-3d

Drafter: PR Date: 10/01/21 Contract Number: 1690022020



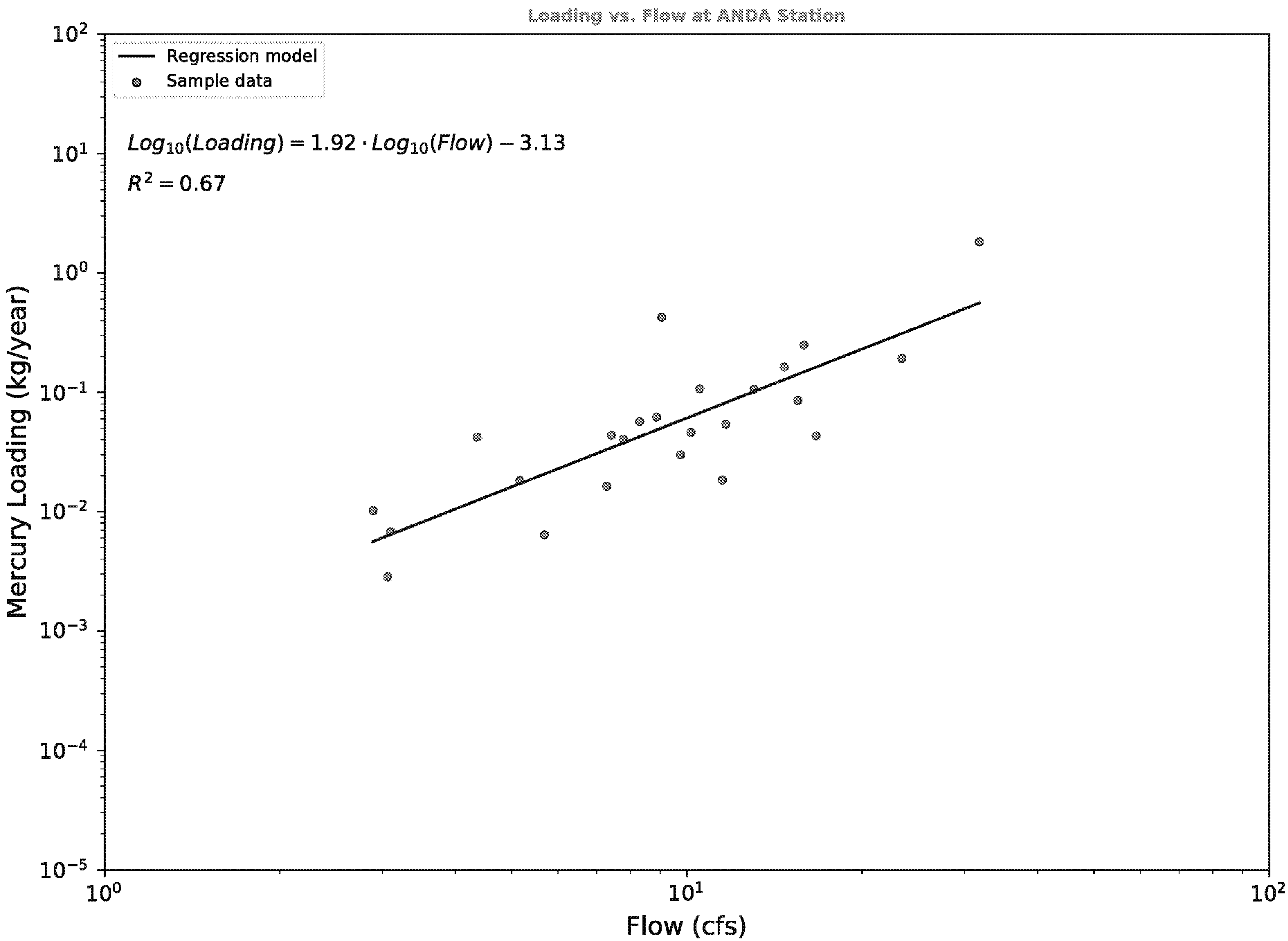
RAMBOLL

Flow and Mercury Mass Loading Regression Analysis - AMER
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-4a

Drafter: PR Date: 10/01/21 Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py



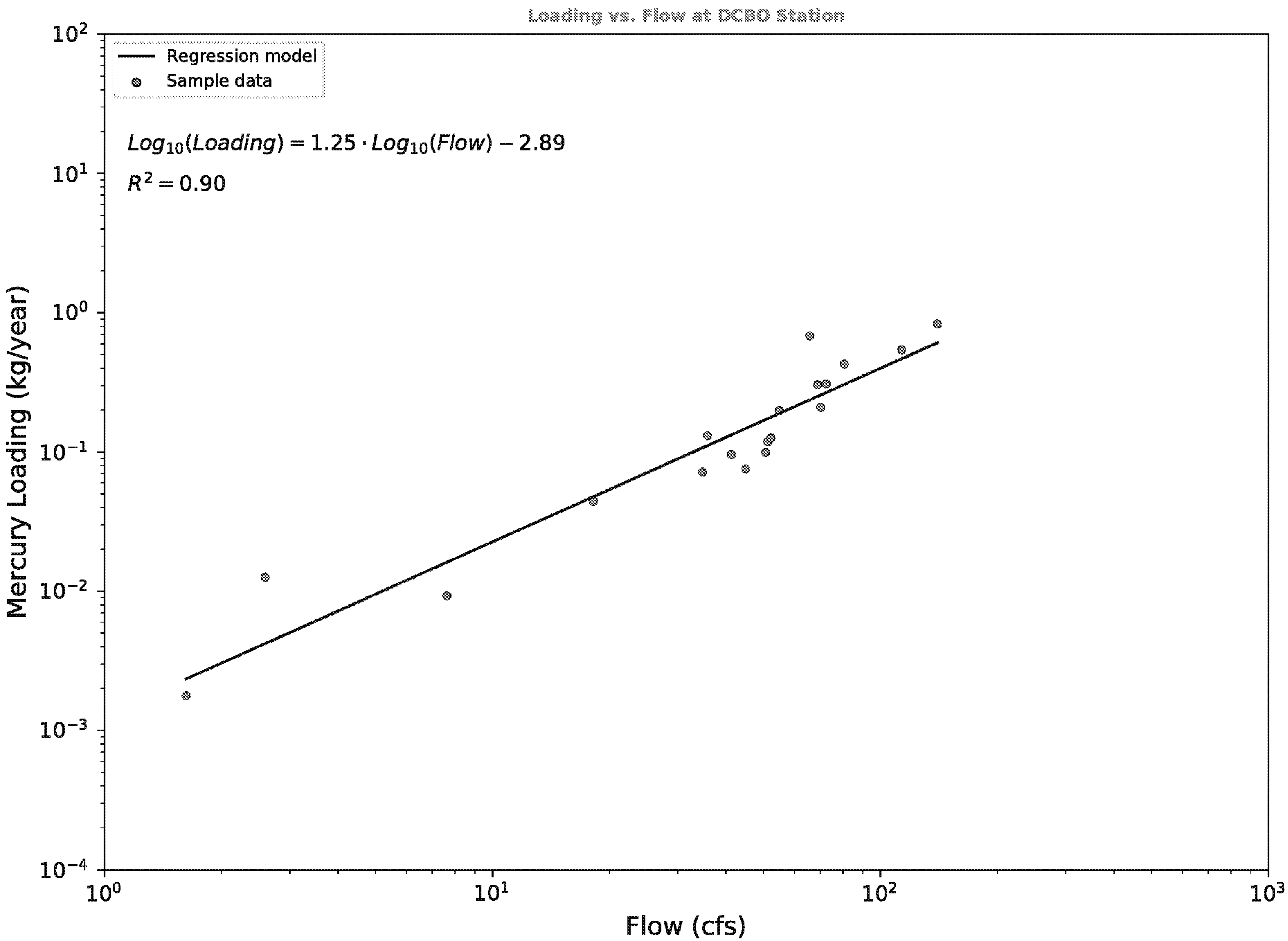
RAMBOLL

Flow and Mercury Mass Loading Regression Analysis - ANDA
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-4b

Drafter: PR | Date: 10/01/21 | Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py



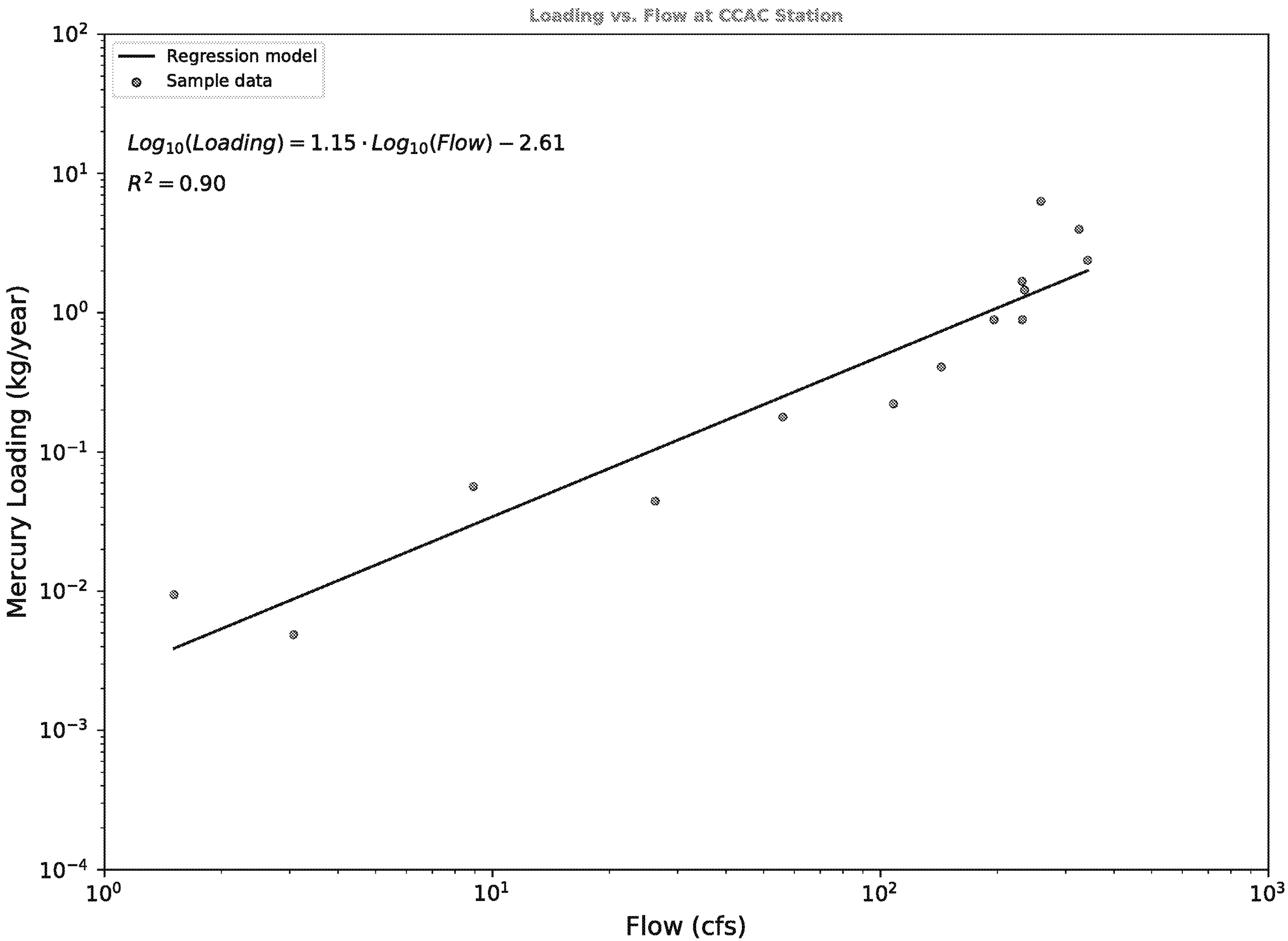
RAMBOLL

Flow and Mercury Mass Loading Regression Analysis - DCBO
Donlin Gold Project
Crooked Creek, Alaska

Figure **3.3-4c**

Drafter: PR Date: 10/01/21 Contract Number: 1690022020

Path: C:\Users\prasouli\OneDrive - Ramboll\Documents\GitHub\Donlin\python\Donlin_Plots_v03.py

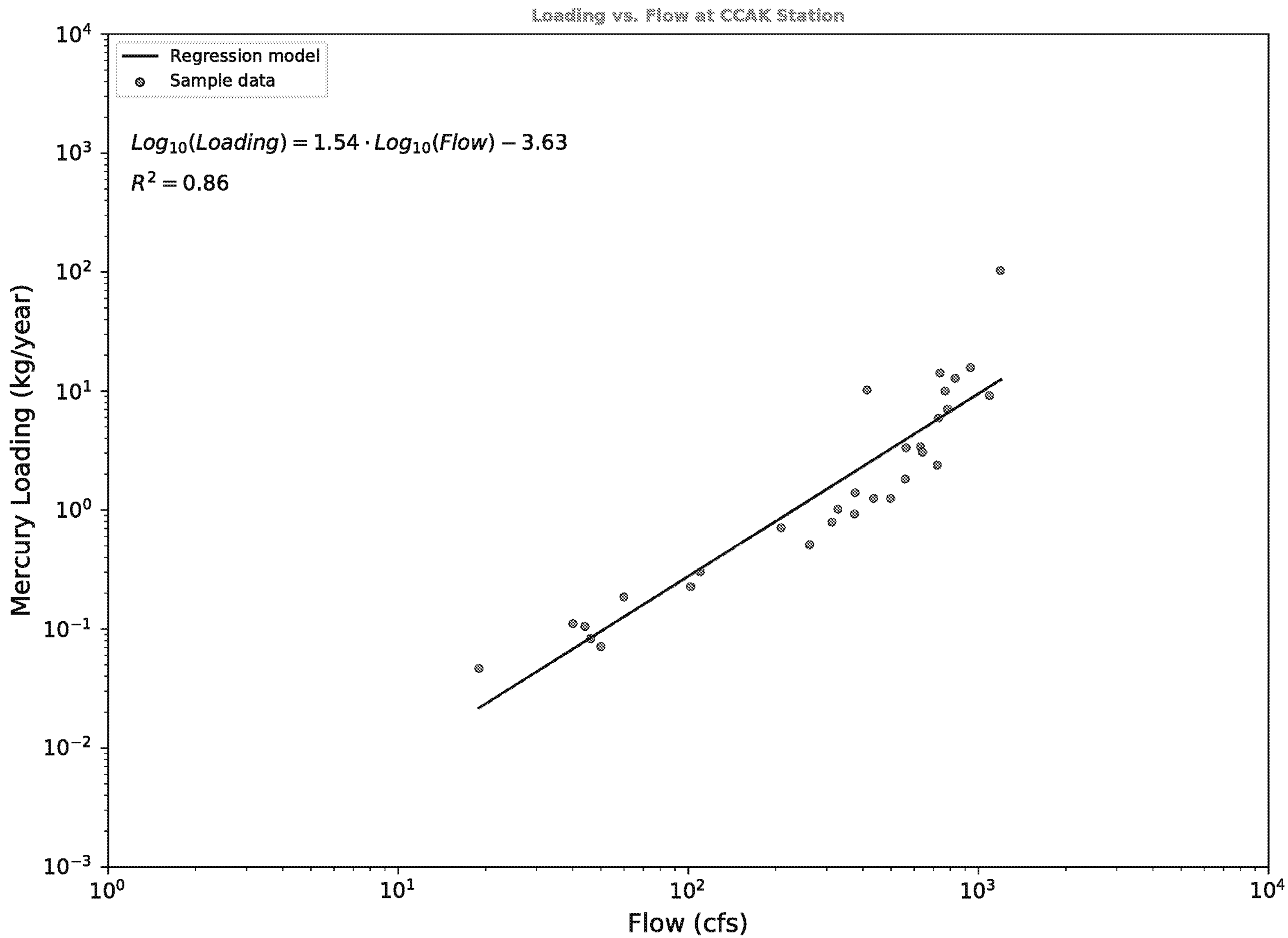


RAMBOLL

Flow and Mercury Mass Loading Regression Analysis - CCAC
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-4d

Drafter: PR | Date: 10/01/21 | Contract Number: 1690022020

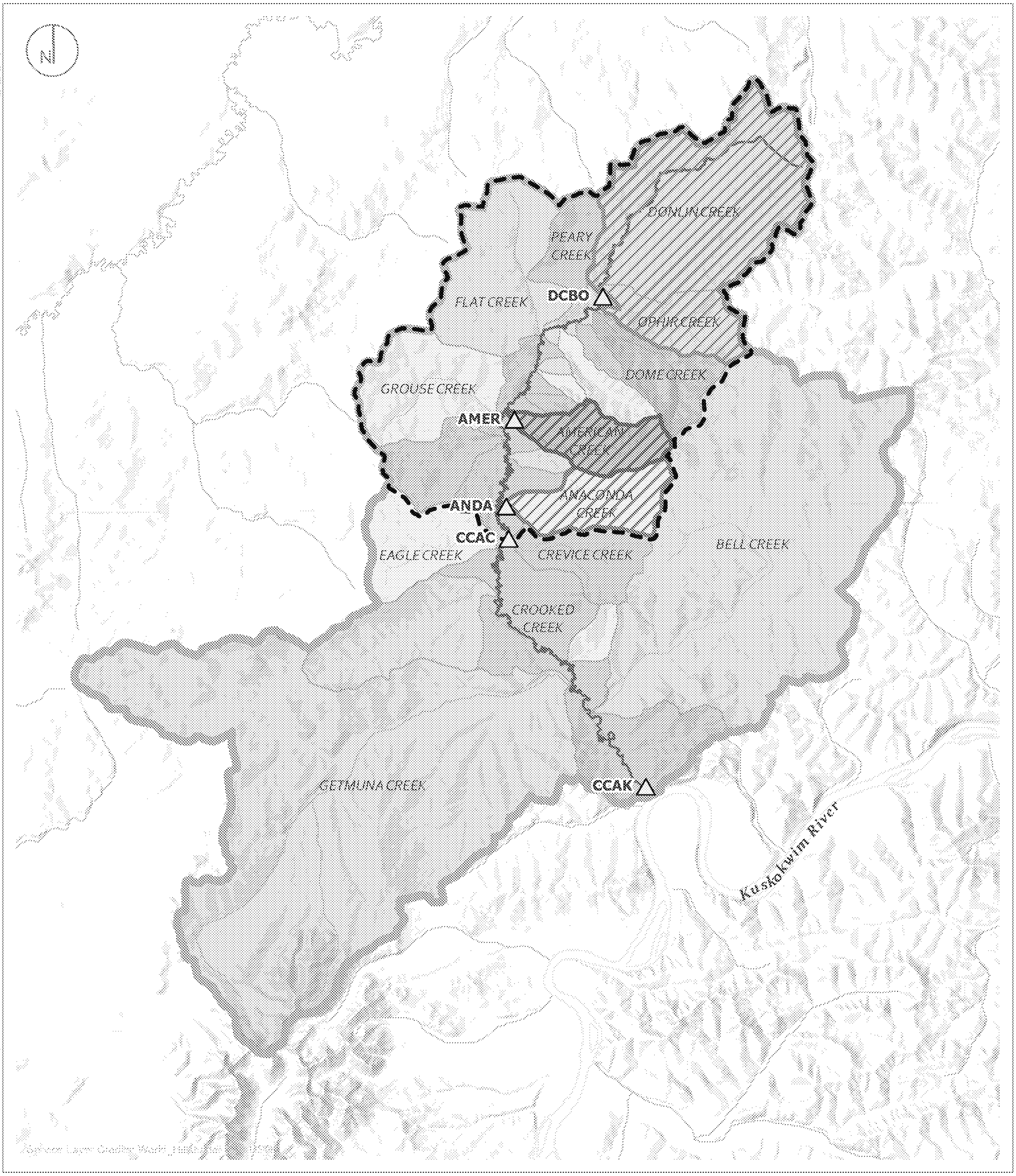


RAMBOLL

Flow and Mercury Mass Loading Regression Analysis - CCAK
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.3-4e

Drafter: PR   Date: 10/01/21   Contract Number: 1690022020



C:\Users\lackerman\Ramboll\Donlin - General\work\water team\report\Section_3_3_Figures.aprx

PROJECT: 1690022020 | DATED: 10/1/2021 | DESIGNER: LACKERMAN

△ Gauging/Water Quality Station
— Crooked Creek, Donlin Creek

Drainage Area
- CCAC
- AMER
- ANDA
- DCBO
- CCAK

0 5 10 Miles

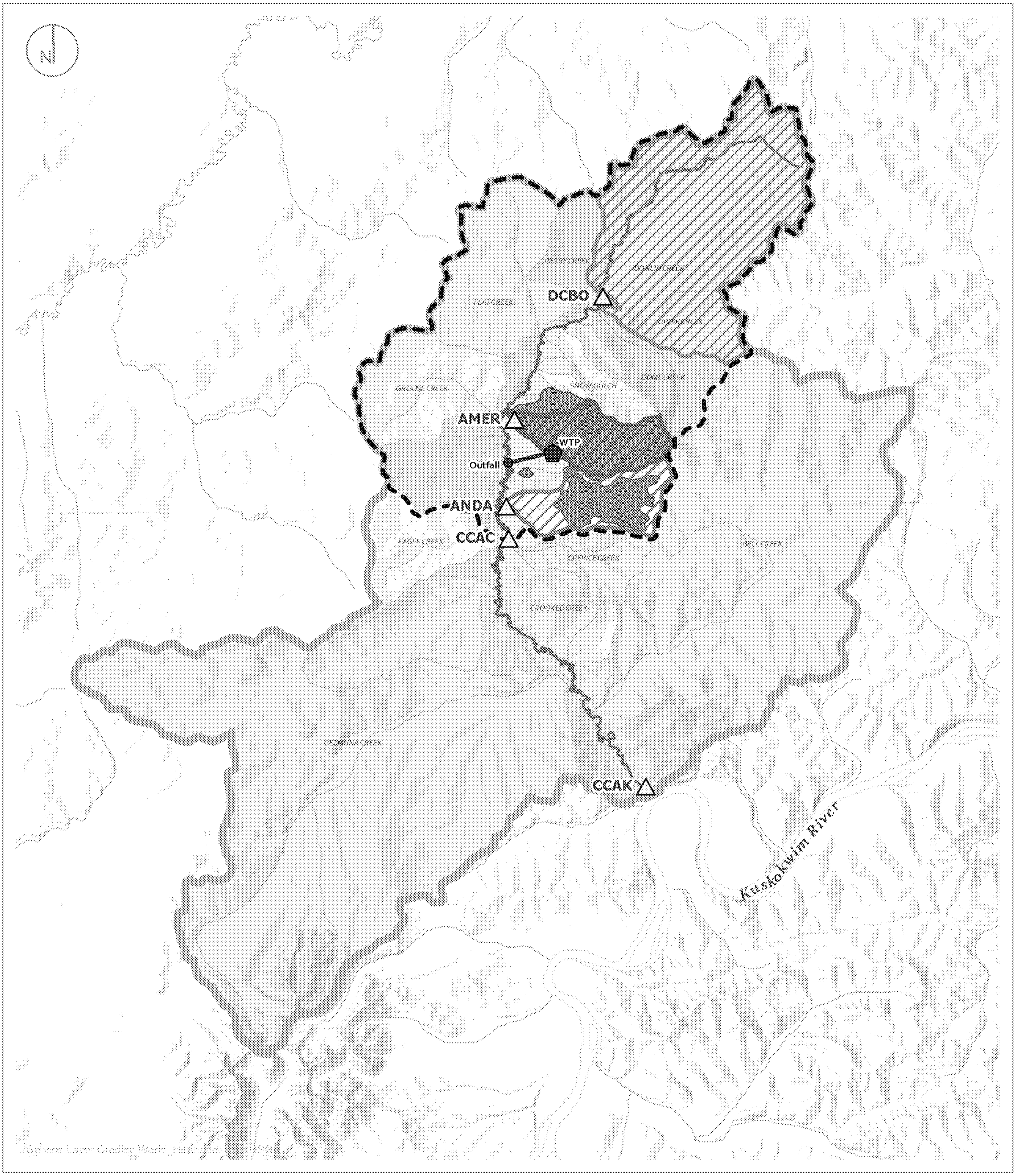
STATION DRAINAGE AREAS FOR MASS BALANCE

Donlin Gold Mine
Alaska

FIGURE 3.3-5

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL



PROJECT: 1690022026 | DATED: 10/1/2021 | DESIGNER: LACKERMAN

- Outfall
- Wastewater Treatment Plant (WTP)
- Gauging/Water Quality Station
- Crooked Creek, Donlin Creek
- Area with Runoff Control

Drainage Area
- CCAC
- AMER
- ANDA
- DCBO
- CCAK

0 5 10 Miles

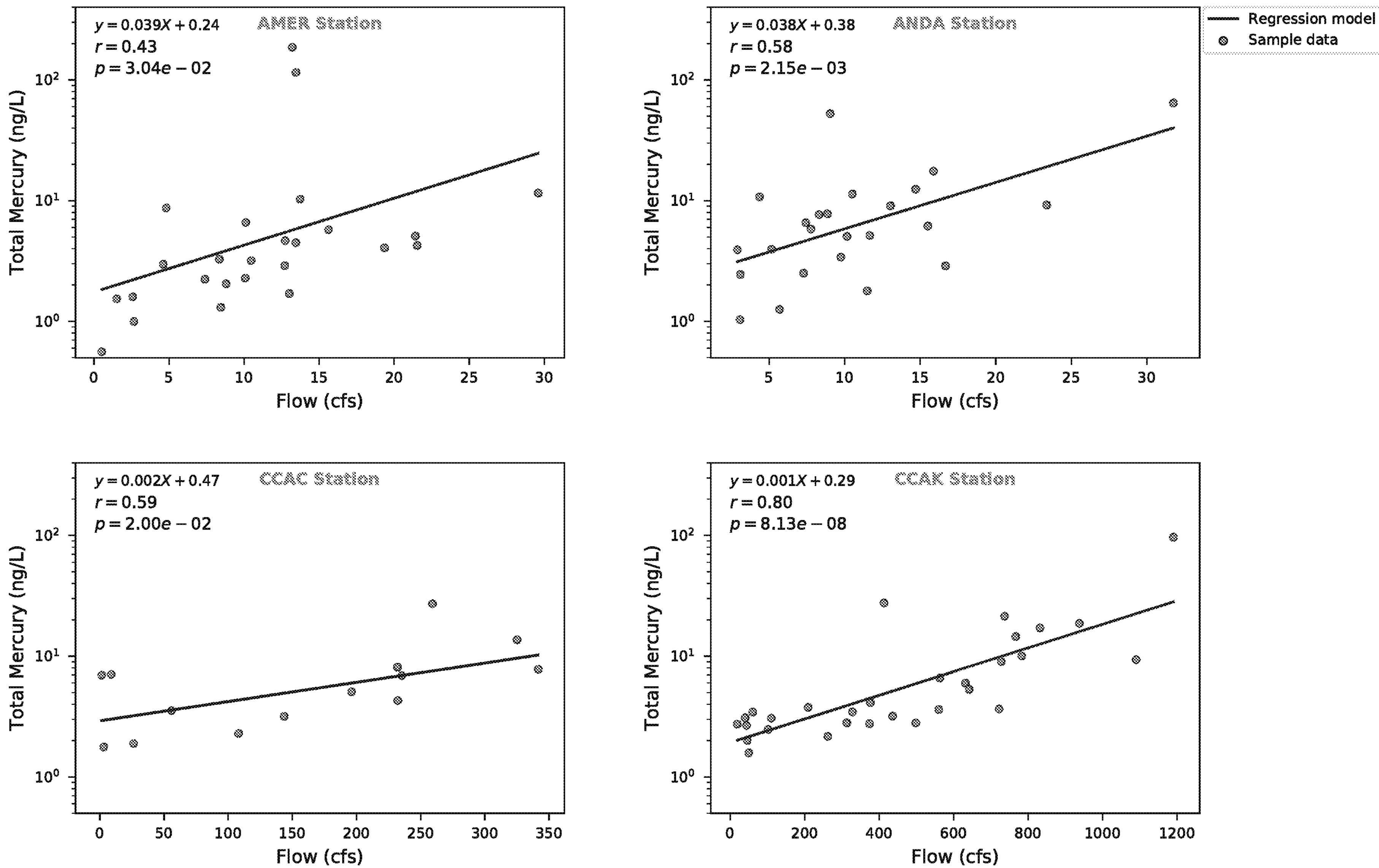
PROJECT CONDITIONS

Donlin Gold Mine
Alaska

FIGURE 3.3-6

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL



RAMBOLL

Total Mercury Concentration vs. Flow
Donlin Gold Project
Crooked Creek, Alaska

Figure
3.4-1

Drafter: PR Date: 10/01/21 Contract Number: 1690022020

Fort Knox TSF & WSR Dam Failure Analysis

Prepared for:

Fairbanks Gold Mining, Inc.
Kinross Gold Corporation
PO Box 73726
Fairbanks, Alaska 99707

Prepared by:

SRK Consulting
Engineers and Scientists

Project Reference Number
073400.040

March 2010

Fort Knox TSF & WSR
Dam Failure Analysis

Fairbanks Gold Mining, Inc.

Kinross Gold Corporation
PO Box 73726
Fairbanks, Alaska 99707

SRK Consulting (U.S.), Inc.
Suite F-40, 4710 Business Park Blvd
Anchorage, AK, USA, 99503

Tel: 907.677.3520 Fax: 907.677.3620
E-Mail: anchorage@srk.com Web site: www.srk.com

SRK Project Number 073400.040

March 2010

Author
Sean Neuffer

Reviewer
Daryl Hockley, P.E.

Executive Summary

The Fort Knox Mine is currently in the process of permitting a 52-foot lift on its tailings storage facility (TSF) that would increase the dam height from 314 feet to 366 feet. The TSF currently has a Class III (low) hazard classification under the State of Alaska Department of Natural Resource's Alaska Dam Safety Program. Fairbanks Gold Mining, Inc. (FGMI) retained SRK to complete a dam failure analysis and prepare inundation maps to be used in the review of the dam's hazard classification and to update the Emergency Action Plan.

FGMI also operates a water storage reservoir (WSR) located approximately 2.2 miles downstream of the TSF. In order to consider a "worst case" scenario, the failure analyses assumed that the WSR embankment would also breach.

The TSF is located approximately 42 miles upstream of Fairbanks, Alaska. The flow path between the TSF and Fairbanks consists primarily of Fish Creek, the Little Chena, and Chena Rivers. Development is present at the lower end of the flow path, between Chena Hot Springs Road and the confluence of the Little Chena and Chena Rivers. The potential for inundation in this region is pertinent for the hazard classification and emergency planning.

The Guidelines for Cooperation with the Alaska Dam Safety Program state recommend "an evaluation of a hypothetical dam failure" as part of the dam classification process. A quantitative analysis of a hypothetical dam breach is required for "certain systems for which the results of a dam failure are not apparent, such as a relatively large dam or reservoir located a long distance upstream from a development that may not be in an apparent floodplain". If the results indicate a significant or high hazard, the guidelines recommend development of an inundation map to support emergency action planning.

To meet these requirements, FGMI requested that SRK examine a range of hypothetical dam breach conditions. The scenarios that were carried through to inundation modeling included a "clear day" breach (i.e. in the absence of flood inputs), a breach under the Probable Maximum Precipitation (PMP), and a breach under rainfall equivalent to one-half of the PMP. For the TSF dam, two types of hypothetical breaches were simulated: one extending to the base of the dam, as would be expected if the dam impounded only water; and another more realistic geometry that takes into account both the relatively shallow pond and the presence of tailings solids behind the dam. The WSR dam was assumed to breach to its base.

Additional simulations were completed to simulate floods arising from the PMP and the half-PMP in the absence of dam breaches. Comparison of the various simulation results showed the contribution of each type of breach to the downstream flood levels.

The simulations were modeled using the Hydrologic Engineering Centers-Hydrologic Modeling Software (HEC-HMS 3.4) and River Analysis Software (HEC-RAS 4.0), both developed by the U.S. Army Corps of Engineers. HEC-HMS was utilized to obtain hydrographs of the dam breaches and precipitation runoff into the study reach. The routing of the hydrographs down the study reach was performed with HEC-RAS. Solids transport was analyzed using simple calculations to show the range of possible tailings release and downstream deposition. The estimated inundation limits for each cross-section were displayed on aerial photographs along with Federal Emergency Management Agency (FEMA) designated floodplains.

The following conclusions were evident:

- Although there are significant limitations to the current ability to analyze tailings dam breaches, the resulting uncertainties do not prevent clear conclusions about the level of flooding downstream of the WSR.
- A hypothetical breach of the TSF and WSR dams would lead to significant flooding extending at least to Chena Hot Springs Road.
- According to the aerial photographs, all structures that are within the inundation limits for the hypothetical dam breaches scenarios are also within the limits of the FEMA designated 100-year and 500-year flood plains.
- The majority of solids released from the TSF will likely be deposited before the flood wave reaches the confluence of Fish Creek and the Little Chena River. Suspended solids will be transported to the Chena River, and a thin film would be deposited over portions of the inundation area.

A revision of the TSF dam's hazard classification is warranted based on the results of this analysis, and the Emergency Action Plan should be updated and include provisions to protect affected parties in the zone of possible inundation.

Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

1.1 Background

Fairbanks Gold Mining, Inc. (FGMI) is in the process of requesting permits for a 52-foot lift on the tailings storage facility (TSF) at the Fort Knox Gold Mine. The lift will increase the height of the TSF dam from 314 feet to 366 feet.

Alaska Administrative Code 11 AAC 93, Dam Safety, defines a hazard potential classification that is used to determine the minimum levels of design, inspection, and oversight that a dam will receive, as well as requirements for emergency planning. Like most dam classification systems, the Alaska system is based on potential problems that would occur if the dam were to fail. It is not based on the physical condition of the structure. In keeping with that approach, the *Guidelines for Cooperation with the Alaska Dam Safety Program* (ADSP) recommends that the dam classification process be supported by "an evaluation of a hypothetical dam failure". If the results indicate a Class II (significant) or Class I (high) hazard, the guidelines recommend development of an inundation map to support emergency action planning.

The TSF currently has a Class III (low) hazard classification. FGMI retained SRK to perform a dam failure analysis to be used in the review of the raised dam's hazard potential classification, and as a basis for updating the Emergency Action Plan (EAP).

1.2 Study Area

Figure 1 displays the location of Fort Knox Gold Mine relative to the City of Fairbanks, Alaska and major rivers in the area. The flow path length between the TSF and Fairbanks is approximately 42 miles.

The stream reaches considered in the inundation analysis are shown in Figure 2. They extend approximately 32 miles between the TSF and the confluence of the Little Chena River and Chena River. Important features include the Water Storage Reservoir (WSR), constructed wetlands between the TSF and the WSR, Fish Creek below the WSR, and the lower portion of the Little Chena River characterized by wide, flat floodplains with thick vegetation.

1.3 Study Approach

The ADSP *Guidelines* recommend a quantitative analysis of a hypothetical dam breach for "certain systems for which the results of a dam failure are not apparent, such as a relatively large dam or reservoir located a long distance upstream from a development that may not be in an apparent floodplain". The TSF dam fits that description, and therefore FGMI requested that SRK complete a quantitative dam breach analysis.

The dam breach analysis was performed in accordance with the ADSP *Guidelines* and with *Evaluation Procedures for Hydrologic Safety of Dams* (ASCE, 1998). In general, dam breach analysis makes use of mathematical models to simulate two distinct processes: the formation of the dam breach and the resulting outflow of water; and the downstream flow of the released water. In the case of tailings dam breaches, the removal and deposition of tailings solids is also commonly included in the analysis.

All three of the above steps were carried out for this study. Uncertainties were analyzed by considering a range of scenarios. For example, two very different TSF dam breach geometries and five different cases of hydrologic inputs were examined. All model results were compared to rule of thumb guidelines, and the patterns apparent in the multiple runs were analyzed to identify dominant effects. The study conclusions reflect both the model results and the subsequent interpretation.

1.4 Previous Work

The following studies were relied upon for inputs to the dam failure analyses:

- John C. Halepaska and Associates, Inc prepared a dam break analysis in November 1995 for the permitting of the original dam construction;
- FEMA has published a Flood Insurance Study (FIS) for the area. It is noted that FEMA only conducted a detailed flood analysis for the Little Chena River up to 10,800 feet upstream of Chena Hot Springs Road. Flood potential upstream of this point was derived from aerial photography during flooding events;
- Knight Piésold and Co. (2009) prepared an evaluation report for the proposed improvements to the TSF. This report provided the elevation-capacity curves of the TSF and WSR and the ½-PMP and PMP volumes for the TSF;
- Technical Paper No. 47 (TP-47) prepared by the US Weather Bureau (1963) provides 24-hour PMP rainfall data for the state of Alaska. This information was utilized for the determination of PMP point values and area correction factors for the Little Chena River basin (excluding the TSF and WSR basins).
- FGMI provided SRK with topographical information obtained from the Fairbanks North Star Borough GIS department. The data consists of 10 foot contours and covers the entire study reach.

1.5 Report Structure

The next three sections of this report discuss the modeling methods and inputs, present the model results, and discuss the identified patterns. Section 5 summarizes the study conclusions. Detailed results are presented in appendices.

2 Modeling Methods

2.1 Dam Breaches

2.1.1 TSF Breach

Methods currently available to estimate dam breach geometry are imprecise. These methods are generally dependant on empirical relationships between initial geometry (dam height and impounded volume) and final breach dimensions derived from historical dam breaches. However, the TSF is atypical for its high embankment with a small fluid reservoir, and for the presence of tailings solids behind the dam.

The current study reflected the uncertainty in the breach formation process by considering two very different breach geometries for the TSF dam, one that follows the patterns seen in historical failures of water dams, and one that takes into account the presence of tailings solids.

- A “TSF Deep Breach” case assumed that the TSF dam would fail in the mode shown by water-retaining dams, meaning that the breach would extend through to its foundation. This case is unlikely considering the geometry and small fluid reservoir of the TSF, but it provides a worst case for assessing downstream inundation.
- A “TSF Shallow Breach” case assumed that the depth of the breach would be limited by the tailings behind the dam. Calculations were completed to assess the mass of tailings that could be mobilized by the available pond or flood water. The depth of the breach was estimated by assuming various final tailings slopes. The calculations are provided in Appendix 1 and show that a more plausible breach depth is about 30 feet.

2.1.2 WSR Breach

The WSR was assumed to breach in all cases. The WSR contains water only, and is more comparable to dams in the historical dam breach records. The WSR was therefore assumed to breach to its full depth.

2.1.3 Breach Development Parameters

Table 1 summarizes the breach parameters for the TSF and WSR. In addition to breach depth, parameters needed to support outflow modeling include the breach width, side slope, and time to failure. The range of TSF breach depths is discussed in the proceeding section. The sensitivity to breach width was examined and an average width equal to the 2.5 times dam height was adopted. Larger breach widths are not possible given the limited water available to move the dam solids. ADSP recommendations were used for the breach side slopes and time to failure.

Table 1: Summary of Breach Parameters

	Dam Height (ft)	Breach Depth (ft)	Average Breach Width (ft)	Breach Side Slope (H:V)	Time to Failure (hrs)
TSF Shallow Breach	366	30	90 (3 x Breach Depth)	1:1	0.5
TSF Deep Breach	366	366	915 (2.5 x Dam Height)	1:1	0.5
WSR	69	69	172 (2.5 x Dam Height)	1:1	0.5
ADSP Recommendations			0.5 - 5 x Dam Height	0.25:1 to 1:1	0.1 to 1.0

2.1.4 Breach Outflows

The dam breach outflows and downstream flooding were modeled using the Hydrologic Engineering Centers Hydrologic Modeling Software (HEC-HMS 3.4) and River Analysis Software (HEC-RAS 4.0), both developed by the US Army Corps of Engineers. HEC-HMS was utilized to obtain hydrographs of the dam breaches and precipitation runoff into the study reach. The routing of the hydrographs down the study reach was performed with HEC-RAS.

HEC-HMS develops a dam breach hydrograph based on either a piping failure (associated with seismic event) or an overtopping failure (associated with a storm event). For overtopping failure, HEC-HMS uses a weir equation to characterize the discharge. For piping failure, an orifice equation is used until the embankment over the opening sloughs, then the program transitions to a weir equation. In addition to the breach parameters discussed above, the model requires:

- Inflow flood volumes;
- Reservoir elevation-capacity curve;
- Initial water surface elevation (WSEL);
- Piping elevation (piping failure only); and
- Piping coefficient (piping failure only).

The TSF flood volumes were obtained from the prior studies conducted by Knight Piésold & Co.

The runoff contributing to the WSR was calculated using the SCS curve method, using precipitation and runoff curve numbers consistent with the values used in the Knight Piésold estimates of the TSF flood volumes. The estimated inflows to the WSR exceeded the available storage volume of 6,315 acre-ft. The WSR was therefore assumed to be full at the time the breaches initiate.

Elevation capacity curves were determined from information provided in Knight Piésold & Co. (2009). The TSF dam crest was assumed to be raised to 1,540 feet. The WSR dam crest was assumed to be at its current elevation of 1,039 ft.

For clear day failure scenarios, the TSF was assumed to be breached by a piping failure. For the flood failure scenarios, overtopping and piping failure modes were analyzed for both the TSF and WSR. Piping failures produced the highest peak discharges and were therefore assumed in all further analyses.

2.2 Flood Routing

2.2.1 Scenarios

In contrast to the uncertainties associated with dam breach formation, the downstream routing of the resulting flood wave is controlled by well understood physical processes. Uncertainties arise primarily from the choice of hydrologic inputs and by the need to reduce complex natural channels to simpler model geometry. To cover the range of hydrologic inputs, five scenarios were considered:

- "Clear day" breach – TSF and WSR volumes at design operating volumes of (6,600 acre-feet and 3,600 acre-feet, respectively) with base flow conditions in Fish Creek and Little Chena River.
- "PMP" – Probable maximum precipitation (PMP) occurring over the entire study area.
- "½-PMP" – One-half the PMP occurring over the entire study area.
- "Local PMP" - TSF impounding 6600 acre-feet plus the Probable Maximum Precipitation (PMP) volume of 10,219 acre-feet. WSR impounding 3,600 acre-feet plus PMP runoff into WSR. Base flow in the downstream reaches.
- "Local ½-PMP" – As above but with runoff volumes equal to one-half of the local PMP.

HEC-RAS simulations were also completed for cases with local and regional PMP or ½-PMP, but no dam breaches. The difference in inundation area between the "breach" and "no breach" cases indicates the contribution of the dams to the downstream hazards.

2.2.2 Hydrologic Inputs

The major watershed boundaries are shown in Figure 3. The Little Chena River has an approximate total drainage area of 399 square miles. Approximately 6% of that drainage area, or about 22 square miles, contributes to the TSF and WSR.

PMP and Half-PMP Runoff

The runoff from the entire Little Chena River for the PMP and ½-PMP events was modeled in order to show the difference in inundation area between the storm events with and without a dam breach. However, it was anticipated that the change in flood stage may be minimal considering the large amount of precipitation and the ratio of watershed contributing to the Little Chena River versus the watershed contributing to the TSF and WSR. The inundation area of a dam breach with the TSF and WSR impounding the ½-PMP and PMP runoff with base flow conditions downstream was also modeled in order to contrast the clear day inundation damage to the damage if a local ½-PMP and PMP were to occur over the TSF and WSR basins only.

Little Chena River

The Little Chena River has an approximate 399 square mile drainage area. 377 square miles contribute to the Little Chena River downstream of the WSR. US Geological Survey (USGS) Quadrangle maps were used to delineate the area into 10 major basins. These basins were further subdivided into a total of 106 subbasins. Figures 3 and 4 display the major and subbasin delineations, respectively. The basins were modeled in HEC-HMS using the SCS curve method. Input parameters for determining the runoff hydrograph include:

- Basin Area;
- Precipitation;
- Runoff Curve Number(RCN);
- Basin Lag Time; and
- Stream/river characteristics.

A 24-hour point PMP of 11 inches was obtained from TP-47 for the basin (excluding TSF and WSR basins). A depth-area factor of 0.87 was applied to the 24-hour point PMP. Digitized NRCS mapping was available from the FNSB GIS website. The basin is generally characterized by class D soils with brush/woods cover. An antecedent moisture condition II (normal) was used to produce a RCN of 77. Typically for PMP analyses, antecedent moisture is assumed to be higher to produce a higher runoff volume; however, for the purposes of this study, decreasing the amount of runoff contributing to the Little Chena River downstream of the WSR will produce more conservative estimates for the difference in damage. The lag time for each basin was estimated using methods obtained from TR-55. Stream and river characteristics were estimated using the USGS quadrangle maps and aerial images. These characteristics were used to determine the lag time for the basins and the lag time for the routing of the subbasins to their confluence with the Little Chena River. Hydrographs were obtained from HEC-HMS at all junctions with the study reach.

2.2.3 HEC-RAS Input Parameters

As noted above, the routing of the dam breach outflow and storm runoff hydrographs was performed using the HEC-RAS model. The model uses continuity and momentum equations to route the flood wave down the study reach. Input parameters for HEC-RAS include:

- cross-section topography;
- cross-section reach lengths;

- Manning's 'n' values;
- Base flows;
- Simulation time;
- Upstream and downstream boundary conditions; and
- Lateral inflows.

Cross-section geometry was obtained from several sources and is discussed in greater detail in Section 2.2.2. The study reach was modeled based on the flow path traveling straight along the valley. The reach lengths correlate to valley flow lengths and not the river alignment. The river meanders considerably. A flood wave of this magnitude will not follow the path of the river, but will travel straight, crossing the overbank areas. Additionally, the cross-section geometry of the Little Chena River was estimated. Greater detail of the river geometry is not necessary considering the volume of the flood wave and small base flows in the river.

Manning's 'n' values were determined from aerial images and prior FEMA studies. FEMA studies used values between 0.002 and 0.13. For this analysis, the overbank areas were assigned Manning's 'n' values of 0.12. This higher value reflects the heavy underbrush in the area and the sediment in the flow from the displaced tails and channel bed scouring that will occur during a breach event.

A base flow of 250 cfs was input into the model for the study reach. This flow is consistent with stream gage data at the Chena Hot Springs Road. This flow is higher than what would be expected in Fish Creek; however, this low flow in inconsequential compared to the flood wave.

The model begins on January 1, 2010 at 0:00 hours. The breach is initiated one hour after the start of the model. The flood wave peak reaches the WSR two hours after the model begins. This time was used for the initiation of the WSR dam breach to model a "worst case" scenario.

The TSF dam breach hydrograph was the upstream boundary condition. HEC-RAS allows several options for a downstream boundary condition. The "normal depth" option with a friction slope of 0.0006 (approximate slope of water surface) was utilized for this analysis.

The runoff hydrographs for the downstream contributing areas as discussed in Section 2.1.1 were input into the model as lateral inflows. HEC-RAS allows for lateral inflows to be introduced to the reach by either a point source or an even distribution over a range of cross-sections. The inflows were input according to how the basin primarily entered the reach. The hydrograph multiplier option was utilized to convert the PMP runoff to the ½-PMP.

A total of seven runs were performed for each of the TSF Shallow Breach and TSF Deep Breach cases. A summary of the runs is shown in Table 2.

Table 2: Summary of HEC-RAS Inputs

Run	TSF volume released (acre-ft)	WSR volume released (acre-ft)	Downstream Conditions
Clear Day- Dam Breach	6,600	3,300	Base Flow
1/2-PMP - No Dam Breach	0	0	1/2-PMP
1/2-PMP - Dam Breach	8,564	6,315	1/2-PMP
PMP - No Dam Breach	0	0	PMP
PMP - Dam Breach	10,219	6,315	PMP
Local 1/2-PMP - Dam Breach	8,564	6,315	Base Flow
Local PMP - Dam Breach	10,219	6,315	Base Flow

2.2.4 Topography

The FNSB GIS topographical data was initially used for the cross-section geometry. Discrepancies between ground elevation data and aerial imagery were found through the course of modeling. It appears that the brush/tree canopy surrounding the river maybe interfering with ground elevation data. This is showing the Little Chena River to be at a higher elevation than the adjacent floodplain and in some cases traveling up hill. Corrections were made to cross-sections that were heavily affected. Figure 5 depicts the correction performed for XS-7. This correction was typical for cross-sections that had clear discrepancies with the topographical data. The modified cross-sections are located downstream of the WSR and upstream of Chena Hot Springs Road (XS-23 through XS-7 in the figures discussed below).

One consequence of altering the cross-sections is that the computed water surface elevations and inundation area cannot be directly correlated to available topographical data. For this reason, aerial imagery was utilized to modify the inundation limits. These modifications consisted of extending the inundation limits to include all visible flow paths in the Little Chena River that were not depicted in the topographical data. The modifications to the inundation limits did not alter the inundation status of any structures and therefore should not affect the hazard classification of the TSF.

The region between Chena Hot Springs Road and the confluence of the Little Chena River and the Chena River contains structures and will be the pertinent region for determining the hazard classification. The topographical data from FNSB in this area did not correlate well with aerial imagery. This region is flat (slopes less than 0.5%) and has heavy vegetation. With 10 foot contour data being possibly influenced by canopy interface, the data is not suitable for this analysis. Cross-sections for this region were obtained from the Halepaska (1995) inundation analysis. The Halepaska report noted that the cross-section geometry was based on FEMA mapping in the area. Utilizing this data enables comparison to the FEMA floodplain. It is noted that the cross-section data does not compare well with the FNSB data at Chena Hot Springs Road (XS-6); however, with the corrections made to the upstream cross-sections discussed above, the ground slope upstream and downstream of this location is consistent. Figure 6 is the HEC-RAS generated profile of the study reach with the cross-section locations represented by vertical lines.

2.2.5 Model Stability

HEC-RAS requires numerical conditions to be met for the convergence of a solution. The dynamic nature and magnitude of the breach hydrographs initially led to model instability. HEC-RAS allows for interpolation of cross-sections and varying time step intervals. These two parameters were adjusted to produce a stable solution. The stable models utilized up to 2,380 interpolated cross-sections and a time step interval of 2 to 5 seconds.

2.3 Solids Analysis

2.3.1 Solids Release

The mobilization of solids in a dam failure is another very complex process, particular where tailings dam breaches are involved. A significant portion of the solids mobilized in previous tailings dam failures occurred as a mudflow, but the more normal processes of suspended and bedload sediment movement play a role in moving solids further downstream. There is currently no deterministic model of the combined effects of these processes. Therefore, simple bounding calculations were used for this study

The basis for the calculations was the amount of solids that could be carried by the available water. At other sites where tailings dams have been breached, the flood water carried up to 50% solids by weight. That solids content is also in the range of slurry densities achieved in hydraulic monitoring systems.

The available water in the TSF Deep Breach case is simply the free water in the TSF corresponding to the clear day, ½-PMP and PMP scenarios. However, the TSF Shallow Breach case assumes that tailings solids within the pond would be eroded, and the associated pore water needs to be added to estimate of available water.

The two sets of calculations are shown in Appendix 1. Table 3 presents the resulting estimates of solids mobilized for each scenario. There is no difference between the PMP and Local PMP estimates, or the ½-PMP and Local ½-PMP estimates.

Table 3: Assumed Volumes of Mobilized Solids

Scenario	Free Water Volume (acre-ft)	Tailings Solids mobilized in TSF Shallow Breach (million cu. ft.)	Embankment Fill mobilized in TSF Deep Breach(million cu. ft.)
Clear Day	6600	423	133
1/2-PMP	8564	550	173
PMP	10219	656	206

2.3.2 Solids Deposition

A similarly simple set of calculations was used to estimate the downstream movement of the solids. The focus was on identifying the range of bulk solids movement and channel burial.

In cases where the mobilized solids are contaminant sources, it can also be important to track the transport of fine materials further downstream. However, neither the embankment materials nor tailings solids at Fort Knox are contaminant sources. The fine material transported downstream would settle out and be indistinguishable from natural sediments.

The simple calculations compared the volume of mobilized solids to the volume of inundated area. Three cases were considered to cover a range of solids deposition:

- Solids are deposited to fill the inundation area from the TSF toe as far as possible downstream.
- Solids are deposited to fill the inundation area in reaches with a 0.5% slope or less.
- The solids are deposited to fill half of the inundated volume along reaches with 0.5% slope.

3 Model Results

3.1 Predicted Breach Outflows

The HEC-HMS breach outflow hydrographs for the TSF Shallow Breach Clear Day, ½-PMP, and PMP scenarios are shown in Figures 2.1 through 2.3 in Appendix 2. There is no difference between the breach outflow hydrographs for the PMP and Local PMP scenarios, or for the ½-PMP and Local ½-PMP scenarios. The comparable HEC-HMS outputs for the TSF Deep Breach scenarios are shown in Appendix 3.

In all cases, the WSR breach produces a higher peak discharge than the TSF breach, even though the WSR has a smaller capacity and lower embankment height. The higher peak discharge is due to the geometry of the reservoir and different breach parameters discussed above. The WSR has a maximum pool depth of 69 feet while the TSF has a maximum pool depth of 15 feet (based on ultimate tailings beach configuration). The additional depth of the WSR increases the initial fluid discharge during a breach event.

3.2 Predicted Downstream Flows

3.2.1 Water Surface Elevation and Flowrates

HEC-RAS outputs for each of the TSF Shallow Breach scenarios are displayed in Tables 2.1 through 2.5 in Appendix 2. Some of the principal outputs are:

- The clear day and the local ½-PMP and PMP scenarios have 95% peak wave flood attenuation by the time the flood wave reaches the Chena River; however, there is still appreciable flow (3,809 to 6,675 cfs) at this location that will overtop the channel banks.
- There is less than a foot stage increase between the dam breach and no dam breach runs for the ½ PMP and PMP scenarios with the storm occurring over the entire basin.
- The velocities at the confluence of the Little Chena River and Chena River are less than 2 feet per second (fps) for the clear day and Local ½-PMP and PMP scenarios and less than 3 fps for the ½-PMP and PMP scenarios with the storm occurring over the entire basin.
- The time to peak flow for the clear day and local events is about 20 hours at Chena Hot Springs Road and 35 hours at the confluence of the Little Chena and Chena Rivers.

The comparable HEC-RAS outputs for the TSF Deep Breach scenarios are provided in Appendix 3.

3.3 Solids Transport and Deposition

Table 2.6 in Appendix 2 shows the results of the solid deposition calculations for the TSF Shallow Breach Local PMP scenario. They indicate that the majority of the solids will likely be deposited before the flood wave reaches the confluence of Fish Creek and the Little Chena River (cross-section 15).

The flow velocities reported in all of the HEC-RAS results are sufficient to keep silt particles in suspension. It is likely that suspended silt will be transported downstream throughout the study area. Some of that sediment will be deposited along stream banks and in off-channel storage zones, leaving a thin film of solids over much of the inundated area.

4 Discussion

4.1 Breach Outflows

Comparison of the TSF outflow hydrographs predicted by the HEC-HMS modeling shows the strong effect of the uncertainties in the TSF breach parameters. (See Figures 2.1 to 2.3 in Appendix 2 and Figures 3.1 to 3.3 in Appendix 3.) The peak outflow from the TSF with a Deep Breach is about 70,000 cfs, whereas the peak outflow from the TSF Shallow Breach is only about 8,000 cfs.

However, the HEC-RAS outputs for the reaches immediately below the WSR have a much narrower range. Table 4 summarizes the flood wave heights and flowrates predicted immediately below the WSR in all of the modeled scenarios. This form of presentation shows that the type of breach at the TSF affects the peak flood wave heights below the WSR by only about 6-8% and the peak flowrates by only about 17-21%. The pattern indicates the importance of the WSR to the overall flood predictions. Because the water level in the WSR is much higher than the pond depth in the TSF, the WSR breach outflow tends to dominate the widely varying inflows from the TSF.

This pattern is fortunate for the interpretation of the downstream HEC-RAS results. It means that the effects of the uncertainty in TSF breach parameters are dampened by the WSR, and therefore do not translate into insurmountable uncertainties downstream. In fact, further examination of Table 4 shows that the uncertainty in the choice of hydrologic condition, i.e. Clear Day or PMP, has a much greater influence on the flood wave below the WSR. The flowrates predicted for breaches under PMP conditions (116,000 cfs) are 63% greater than those predicted for Clear Day breaches (71,000 cfs).

Table 4: Estimated Flows below WSR (cross-section 24)

Hydrologic Scenario	Peak Flood Wave Height (ft)			Peak Flowrate (cfs)		
	TSF Deep Breach	TSF Shallow Breach	Difference	TSF Deep Breach	TSF Shallow Breach	Difference
Clear Day	22.9	21.3	8%	86,000	71,000	21%
Local 1/2-PMP	26.7	25.2	6%	132,000	113,000	17%
Local PMP	27.2	25.5	7%	138,000	116,000	19%
Regional 1/2-PMP	26.7	25.2	6%	132,000	113,000	17%
Regional PMP	27.2	25.5	7%	138,000	116,000	19%

4.2 Flood Wave Attenuation

The HEC-RAS results from the many scenarios generally show the expected patterns of attenuation as the flood waves travel downstream. Table 5 shows selected HEC-RAS results for the TSF Shallow Breach – Clear Day as an example.

A rule of thumb that is sometimes used in "back of envelope" calculations is that the flood peak should reduce by half over each 10 miles of downstream travel. The results in Table 5 follow that pattern exactly over the first ten miles to cross-section 14. The attenuation between cross-sections 14 and 8 is less than the rule of thumb would suggest. However, the rule of thumb does tend to over-estimate attenuation in shallow sloping channels.

The flood wave appears to not attenuate at all over the ten-mile stretch between cross-sections 8 and 1. However closer examination shows that the flood wave continues to decrease in height until cross-section 4, and then increases. The increase below cross-section 4 is probably an artifact of the boundary condition applied in the model at cross-section 1. Based on USGS stream gage data and FEMA mapping, the Chena River reaches flood stage around 12,000 cfs and has average annual peak stream flows under 3,000 cfs. Based on this information, the Chena River has capacity to handle the potential flows from dam breaches.

Table 5: Flood Wave Attenuation for TSF Shallow Breach – Clear Day Scenario

	Distance from TSF	Peak Water Level Elevation (ft WSEL)	Channel Base Elevation (ft)	Flood Wave Height (ft)
Section 24	3.2	979.9	958.6	21.3
Section 14	12.9	725.4	714.0	11.4
Section 8	24.0	511.4	503.9	7.5
Section 4	28.5	479.7	474.1	5.6
Section 1	32.6	464.4	456.3	8.1

4.3 Flood Levels at Chena Hot Springs Road

Further patterns in the HEC-RAS results become more apparent if the focus is placed on one location. Chena Hot Springs Road is represented by cross-section 6 in the model. Table 6 summarizes the flood elevations predicted for cross-section 6 under each of the modeled scenarios.

The table includes the No Breach scenarios. It is interesting to compare the flood levels predicted for the No Breach PMP or ½-PMP scenarios to those predicted for the breach scenarios. The peak flood elevation of 499.6 for the No Breach Regional PMP is much higher than the flood levels expected for dam breaches in the absence of a regional PMP. That result is not unexpected; regional PMP's are extremely rare events and would certainly create very significant floods. Interestingly though, even the flood level of 496.1 predicted for the No Breach ½-PMP is much higher than those for the breach scenarios without regional storms. The ½-PMP has no statistical meaning, but is probably something like the 500-year storm. In other words, it is far more likely than a PMP. These results suggest that the flooding associated with Clear Day or Local PMP breaches of the TSF and WSR dams would be within the range of natural floods that the stream channel would experience.

Table 6: Estimated Flood Levels at Chena Hot Springs Road (cross-section 6)

Hydrologic Scenario	Peak Flood Elevation (ft)			Surcharge due to Breaches (ft)		
	No Breach	TSF Deep Breach	TSF Shallow Breach	TSF Deep Breach	TSF Shallow Breach	Difference
Clear Day	487.2	491.0	490.2	3.8	3.0	0.8
Local 1/2-PMP	487.2	492.0	491.0	4.8	3.8	1.0
Local PMP	487.2	492.3	491.3	5.1	4.1	1.0
Regional 1/2-PMP	496.1	496.9	496.8	0.8	0.7	0.1
Regional PMP	499.6	500.2	500.2	0.6	0.6	0.0

As noted above, the primary reason for running the No Breach cases was so that the effects of the dam breaches could be distinguished from the effects of the PMP or ½-PMP in surrounding reaches. Subtracting the No Breach flood elevations from the flood elevations predicted for each breach scenario allows the flood surcharge associated with the dam failures to be determined. The right half of Table 6 shows those results.

Several patterns are noteworthy. First, the flood surcharges associated with the Clear Day, Local ½-PMP and Local PMP scenarios are clearly significant, ranging from 3.0 to 5.1 feet. Given the wide shallow sloping floodplains in the area, this level of surcharge would cause extensive flooding. Second, the range of surcharge predictions for the Clear Day, Local ½-PMP and Local PMP scenarios is relatively small. As the last column of Table 6 shows, even the wide uncertainty in the TSF breach parameters produces relatively little uncertainty in predicted flood levels at the Chena Hot Springs Road. These two patterns together indicate that one can safely conclude that failure of the TSF and WSR dams would cause significant flooding at Chena Hot Springs Road.

The third pattern evident in the right half of Table 6 is the relatively small contribution of the dam breaches to flood levels in cases where regional PMP or ½-PMP events are occurring. That pattern is not surprising given that the catchments reporting to the TSF and WSR represent only 6% of the total drainage area reporting to the Little Chena River.

4.4 Inundation Mapping

Mapbook 1 in Appendix 4 displays inundation limits from the HEC-RAS model runs for the TSF Shallow Breach Clear Day, Local ½-PMP and Local PMP scenarios. Mapbook 2 in Appendix 5 shows the comparable results for the TSF Deep Breach scenarios. The mapbooks include aerial imagery flown in 2007 by the US Department of Agriculture. FEMA designated floodplains are also shown. Structures in or around the study reach were identified from the aerial images and are labeled on the maps.

The inundation limits are approximate only. As discussed earlier, there are discrepancies between flood elevations reported from HEC-RAS and flood elevations obtained from contour data on the inundation maps.

Despite the uncertainties, it is clear that there are structures within the flood area. One is an inactive placer mining operation located approximately four miles downstream of the WSR. The portion of Chena Hot Springs Road that passes through the floodplain, and the structures immediately north and south of it, would be threatened by any of the modeled floods. There are many homes located in the inundation area between Chena Hot Springs Road and the confluence of the Little Chena River with the Chena River.

Precise comparison to the FEMA designated floodplains is problematic due to the differences in topography. The inundation indicated by the HEC-RAS results exceeds the FEMA floodplain in Fish Creek and the reaches just below the confluence with the Little Chena River. In reaches closer to Chena Hot Springs Road, the HEC-RAS results indicate floodplains that are more similar in width to the FEMA floodplains. Most of the structures that fall within the HEC-RAS floodplains also fall within the FEMA floodplains.

4.5 Implications for Dam Classification

The ADSP Guidelines use the following property damage criterion for distinguishing between Hazard Class III (low) and Hazard Class II (Significant):

- Class III – Limited impact to rural or undeveloped land, rural or secondary roads, and structures. Loss or property damage limited to the owner of the barrier.
- Class II – Probable loss of or significant damage to homes, occupied structures, commercial or high-value property, major highways, primary roads, railroads or public utilities, or other significant losses or damage not limited to the owner of the barrier.

The inundation mapping discussed above, and the predicted flood levels at Chena Hot Springs Road, indicate that the current Class III designation for the TSF dam may need to be reviewed.

5 Conclusions and Recommendations

The following conclusions can be drawn from the analyses of hypothetical failures of the Fort Knox TSF and WSR dams:

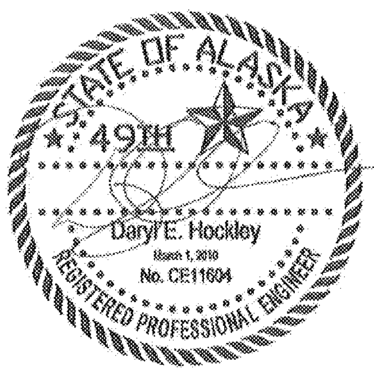
- Although there are significant limitations to the current ability to analyze tailings dam breaches, the resulting uncertainties do not prevent clear conclusions about the level of flooding downstream of the WSR.
- A hypothetical breach of the TSF and WSR dams would lead to significant flooding extending at least to Chena Hot Springs Road.
- According to the aerial photographs, all structures that are within the inundation limits for the hypothetical dam breaches scenarios are also within the limits of the FEMA designated 100-year and 500-year flood plains.
- The majority of solids released from the TSF will likely be deposited before the flood wave reaches the confluence of Fish Creek and the Little Chena River. Suspended solids will be transported to the Chena River, and a thin film would be deposited over portions of the inundation area.

A revision of the TSF dam's hazard classification is warranted based on the results of this analysis, and the Emergency Action Plan should be updated and include provisions to protect affected parties in the zone of possible inundation.

This report, "**Fort Knox TSF & WSR Dam Failure Analysis**", was prepared by SRK (Consulting) US Inc.

Sean Neuffer, EI
Staff Engineer

Under the supervision of Daryl Hockley, P.E., Principal.



ED_014329A_00000114-00159

References

John C. Halepaska & Associates, Inc. *Evaluation of Downstream Inundation due to Fluid Loss from Tailings and Water Supply Structure*, Fort Knox Project, Fairbanks Alaska. November 1995.

Knight Piésold and Co. *Tailings Storage Facility Expansion Geotechnical and Hydrological Evaluation Report*. November 2009.

American Society of Civil Engineers, Task Committee on Spillway Design Flood Selection of the Committee on Surface Water Hydrology of the Hydraulics Division. *Evaluation Procedures for Hydrologic Safety of Dams*. 1988

Alaska Department of Natural Resources. *Guidelines for Cooperation with the Alaska Dam Safety Program*. June 2005

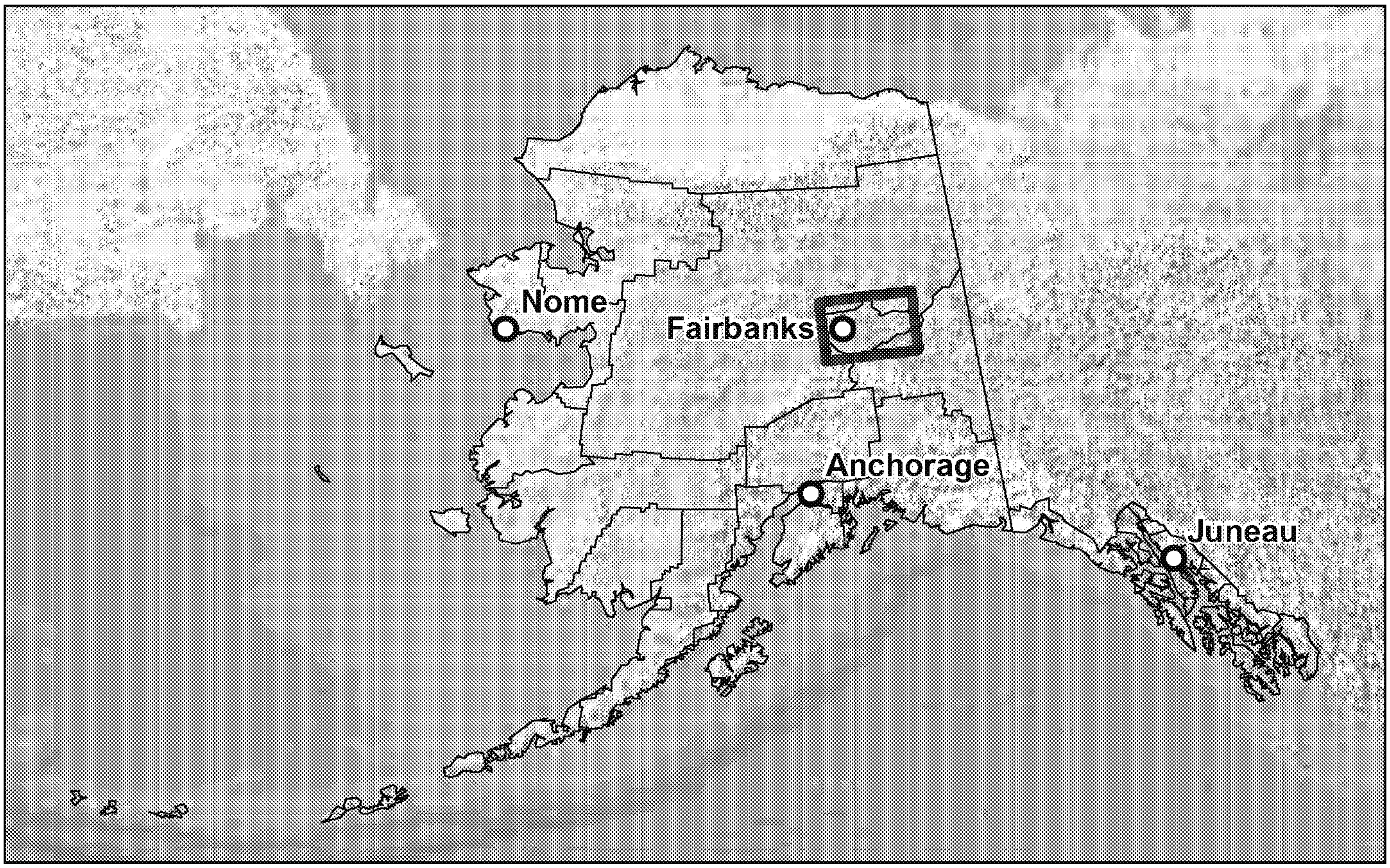
Federal Emergency Management Agency. *Flood Insurance Study, Fairbanks North Star Borough, Alaska*. Revised January 1992.

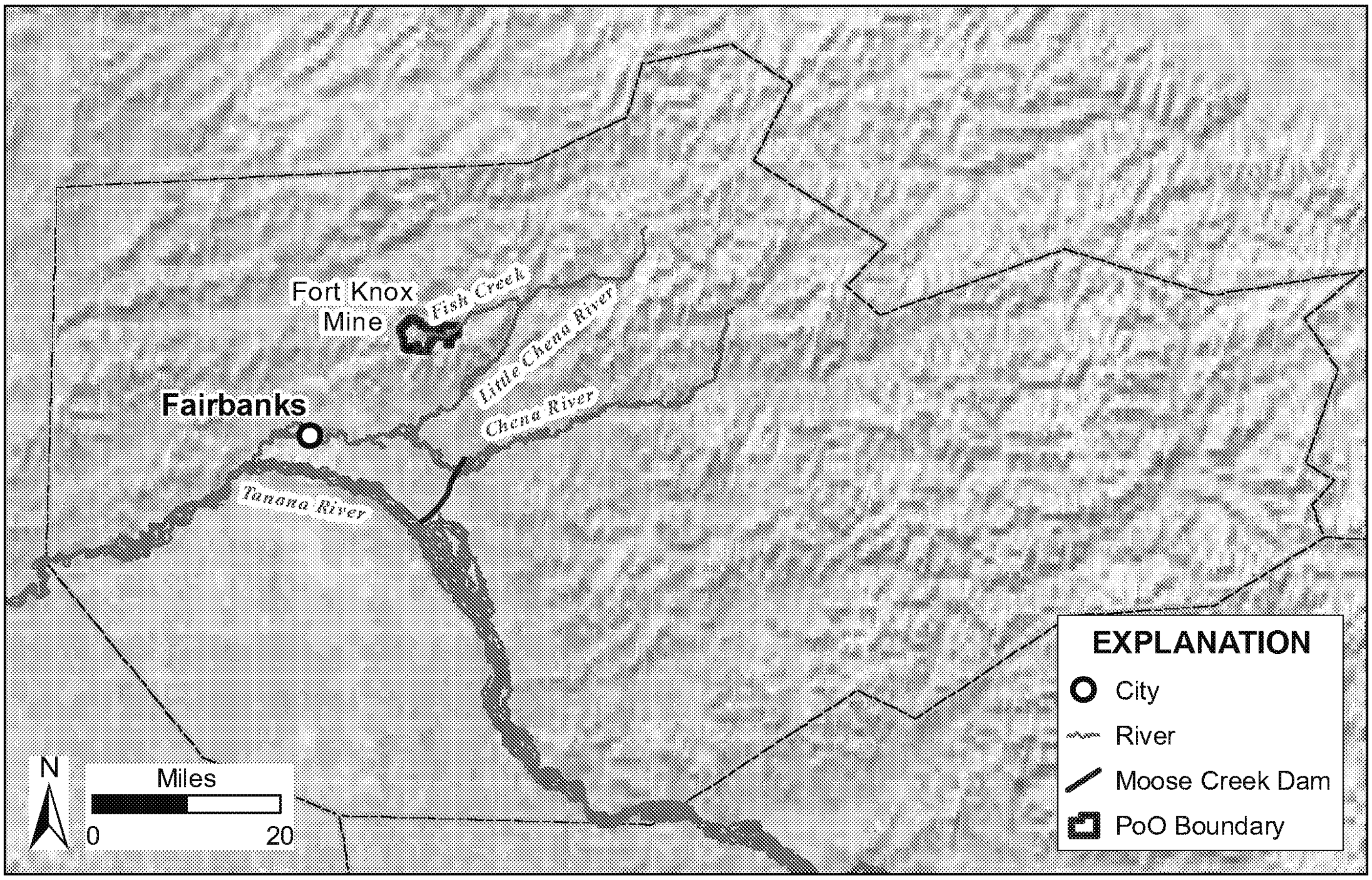
United States Department of Commerce, Weather Bureau. *Technical Paper No.47, Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska*. 1963

United States Department of Agriculture, Natural Resources Conservation Service. *Technical Release 55, Urban Hydrology for Small Watersheds*. June 1986.

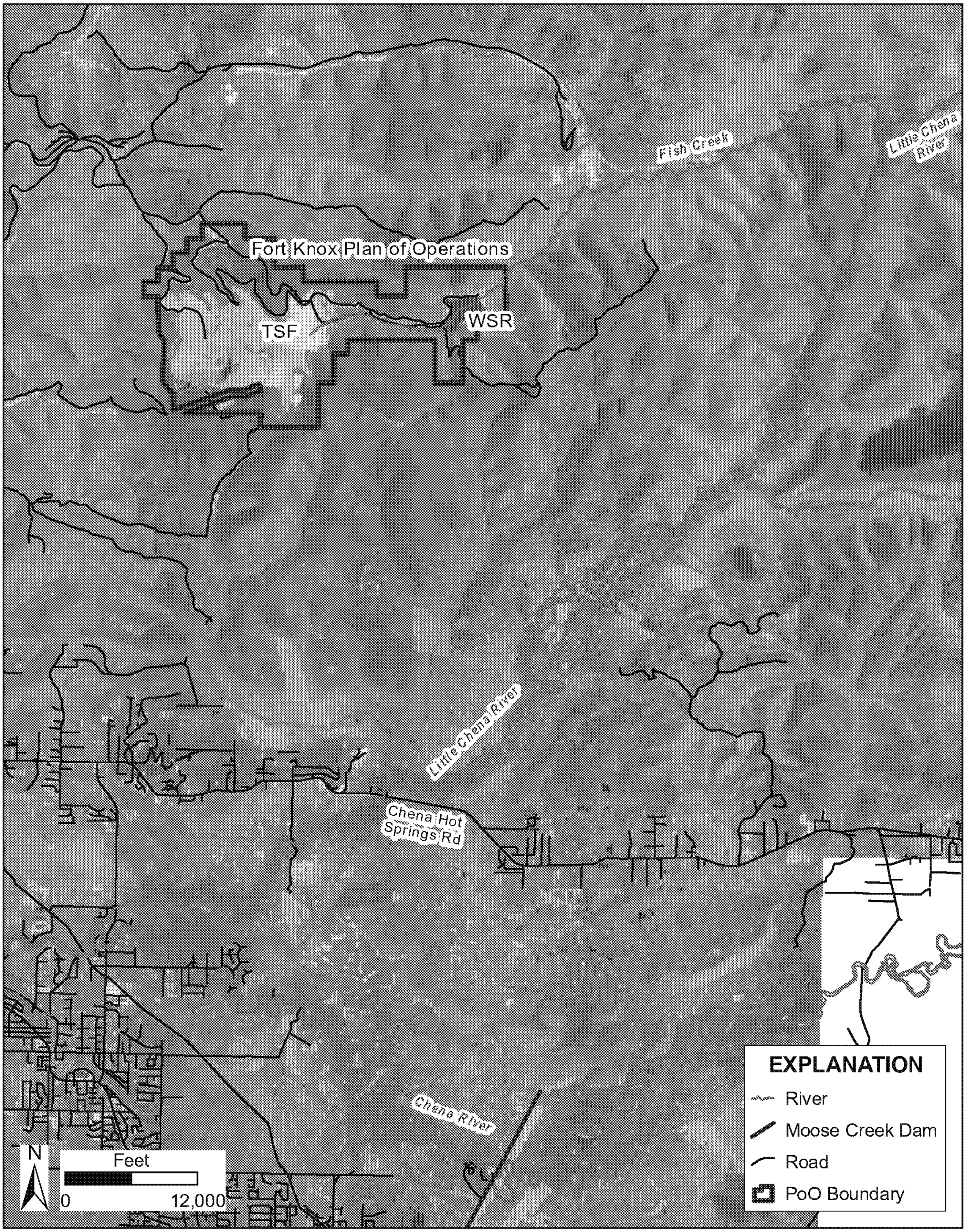
United States Department of the Interior, Bureau of Reclamation, Dam Safety Office. *Prediction of Embankment Dam Breach Parameters*. July 1998.

Figures





SRK Consulting Engineers and Scientists			FAIRBANKS GOLD MINING, INC. FORT KNOX MINE	DRAWING TITLE: PROJECT LOCATION	
NAD 83 State Plane Alaska Zone 3 Feet					
DESIGN: SN	DRAWN: BVB	REVIEWED: DH		DRAWING NO. FIGURE 1	REVISION NO. A
SCALE: 1 inch = 20 miles		DATE: 03/01/2010		SRK JOB NO. 73400.040	
FILE NAME: Fig01_Project_Location_BVB_20100301.mxd					



SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

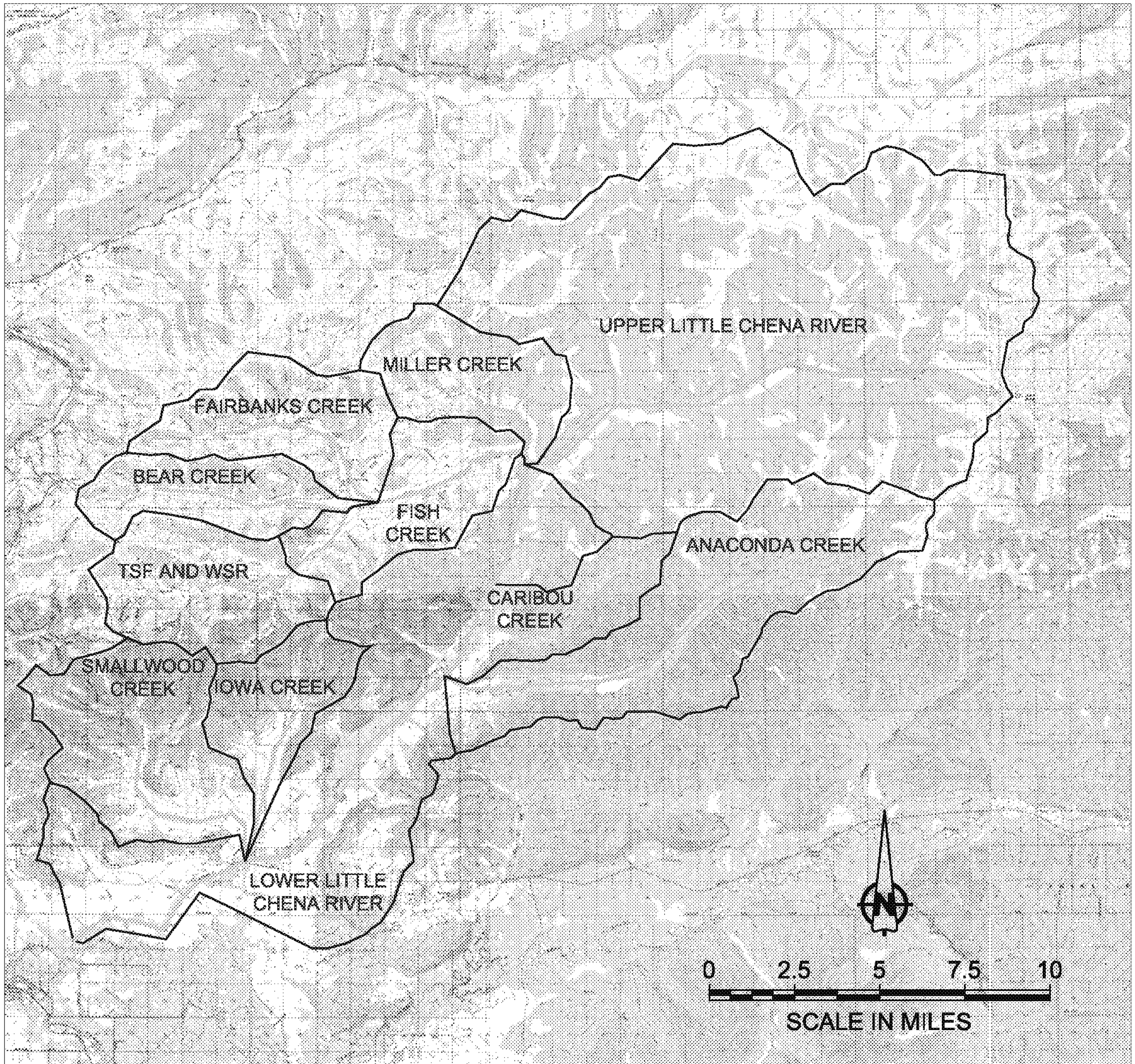
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 12,000 feet			DATE:	03/01/2010
FILE NAME:	Fig02_Study_Reach_BVB_20100301.mxd				

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
STUDY REACH MAP

DRAWING NO. **FIGURE 2**
SRK JOB NO. **73400.040**
REVISION NO. **A**

K:_SITES\Fort Knox\073400.040- Ft Knox TSF Dam Break\040_AutoCAD\HEC-HMS\Basins.dwg

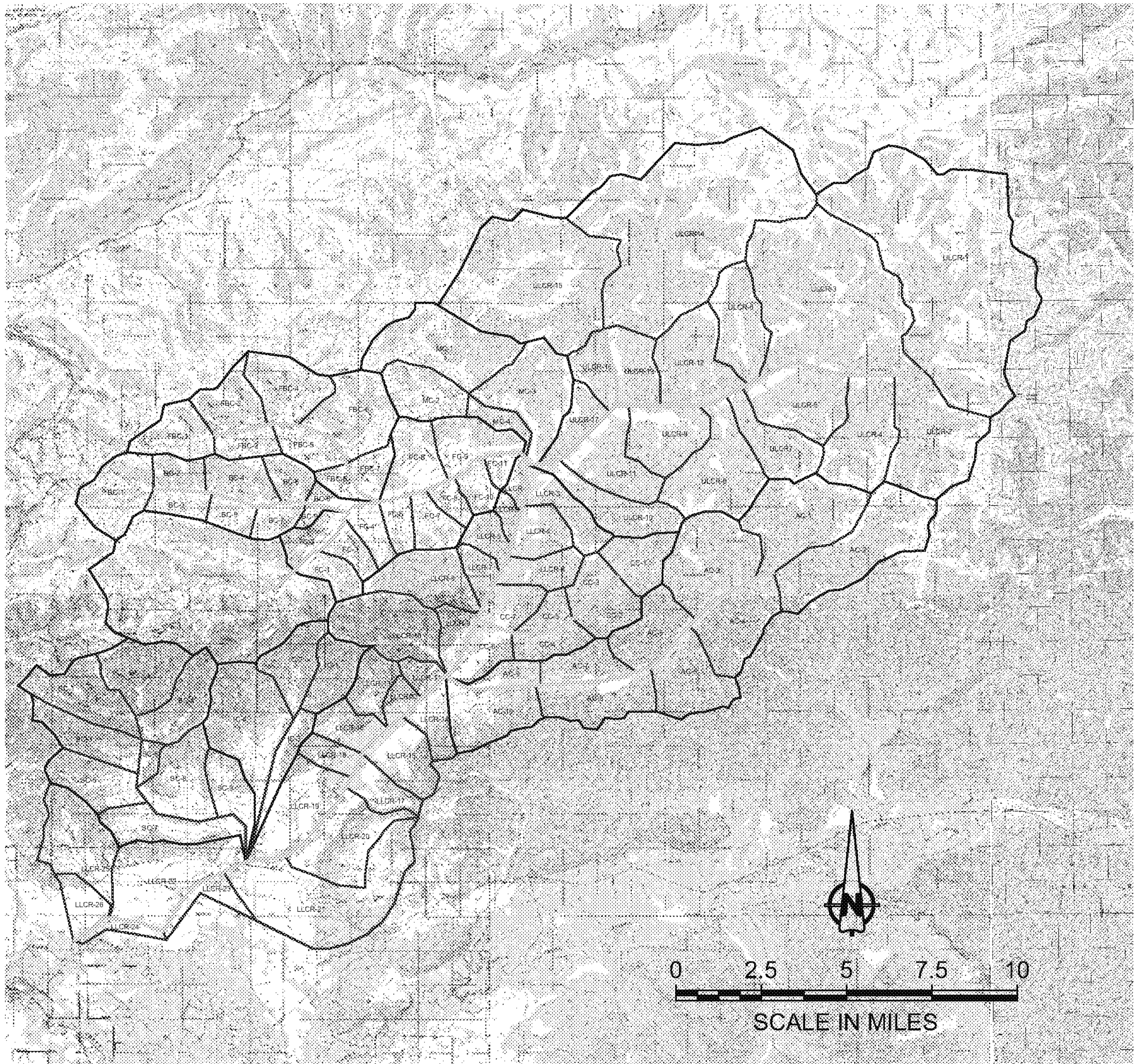


SRK Consulting
Engineers and Scientists

SRK JOB NO.: 73400.040	FIGURE 3	DAM BREAK INUNDATION ANALYSIS
FILE NAME: Basins.dwg	FAIRBANKS GOLD MINING, INC. FORT KNOX MINE	MAJOR BASIN MAP

DATE:	APPROVED:	FIGURE:	REVISION NO.
JAN. 2010			0

Little Chena River Watershed - Basin Summary					
Basin	Subbasin	Area		RCN	Lag Time (min)
		Subbasin (acres)	Basin (sq. mi.)		
Bear Creek	BC-1	2403	14.18	77	35.5
	BC-2	935			41.8
	BC-3	530			47.1
	BC-4	1382			50.1
	BC-5	502			44.1
	BC-6	370			34.7
	BC-7	799			41.3
	BC-8	444			33.0
	BC-9	398			44.3
Fairbanks Creek	FBC-1	1780	19.83	77	44.3
	FBC-2	1795			45.3
	FBC-3	963			41.0
	FBC-4	2836			47.1
	FBC-5	1285			58.1
	FBC-6	2575			49.1
	FBC-7	938			57.7
	FBC-8	382			33.8
Miller Creek	MC-1	4283	18.38	77	58.9
	MC-2	2081			44.1
	MC-3	3503			53.7
	MC-4	692			55.8
Upper Little Chena River	ULCR-1	27597	135.65	77	71.4
	ULCR-2	4694			55.8
	ULCR-3	11677			72.9
	ULCR-4	8941			50.7
	ULCR-5	5215			36.3
	ULCR-6	2657			49.3
	ULCR-7	7182			43.0
	ULCR-8	3803			48.4
	ULCR-9	3961			47.5
	ULCR-10	3270			83.8
	ULCR-11	3984			51.0
	ULCR-12	3279			31.8
	ULCR-13	1893			57.1
	ULCR-14	15239			77.7
	ULCR-15	9583			44.5
	ULCR-16	1254			38.8
	ULCR-17	1349			71.0
Caribou Creek	CC-1	1888	15.38	77	34.3
	CC-2	1309			46.3
	CC-3	935			49.1
	CC-4	1345			55.6
	CC-5	768			57.5
	CC-6	1284			49.3
	CC-7	1380			57.3
Anaconda Creek	AC-1	4227	44.02	77	46.3
	AC-2	4687			35.7
	AC-3	2871			49.4
	AC-4	7801			31.9
	AC-5	2189			84.1
	AC-6	3949			41.0
	AC-7	1475			39.4
	AC-8	3901			51.8
	AC-9	546			75.3
	AC-10	3612			96.3
Iowa Creek	IC-1	1821	13.89	77	45.7
	IC-2	1596			47.8
	IC-3	1087			118.6
	IC-4	4213			100.0
Smallwood Creek	SC-1	2365	27.87	77	55.1
	SC-2	1332			41.9
	SC-3	1397			57.6
	SC-4	3113			90.8
	SC-5	2043			55.8
	SC-6	482			96.4
	SC-7	2330			182.1
	SC-8	3397			69.4
	SC-9	1463			71.3
Fish Creek	FC-1	1009	18.13	77	29.2
	FC-2	1047			50.7
	FC-3	810			42.7
	FC-4	971			47.3
	FC-5	810			39.2
	FC-6	1988			47.8
	FC-7	1257			37.1
	FC-8	531			42.2
	FC-9	1898			34.9
	FC-10	838			40.0
	FC-11	442			38.4
Lower Little Chena River	LLCR-1	435	70.96	77	43.8
	LLCR-2	1621			43.3
	LLCR-3	413			34.2
	LLCR-4	1419			28.6
	LLCR-5	910			33.2
	LLCR-6	1286			34.5
	LLCR-7	814			82.8
	LLCR-8	2349			50.5
	LLCR-9	395			88.3
	LLCR-10	2330			50.5
	LLCR-11	631			70.1
	LLCR-12	602			35.4
	LLCR-13	1289			38.9
	LLCR-14	1217			41.3
	LLCR-15	1979			73.7
	LLCR-16	1253			46.3
	LLCR-17	1240			72.5
	LLCR-18	838			83.8
	LLCR-19	3948			138.8
	LLCR-20	3193			114.5
	LLCR-21	8515			223.4
	LLCR-22	4282			198.9
	LLCR-23	1016			188.8
	LLCR-24	307			157.0
	LLCR-25	2081			75.4
	LLCR-26	1334			118.4



SRK Consulting
Engineers and Scientists

FIGURE 4

DAM BREAK INUNDATION ANALYSIS

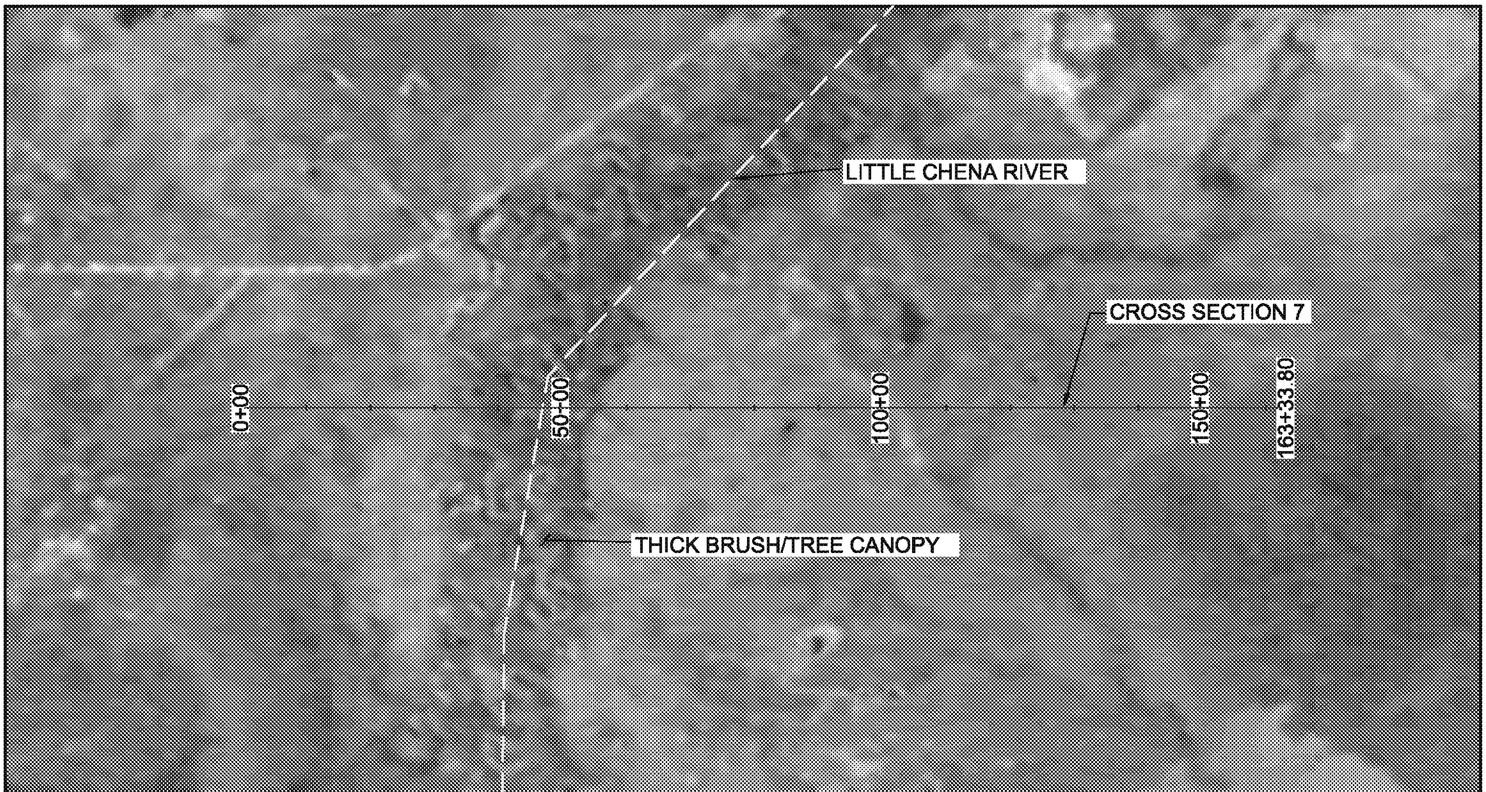
SUBBASIN MAP

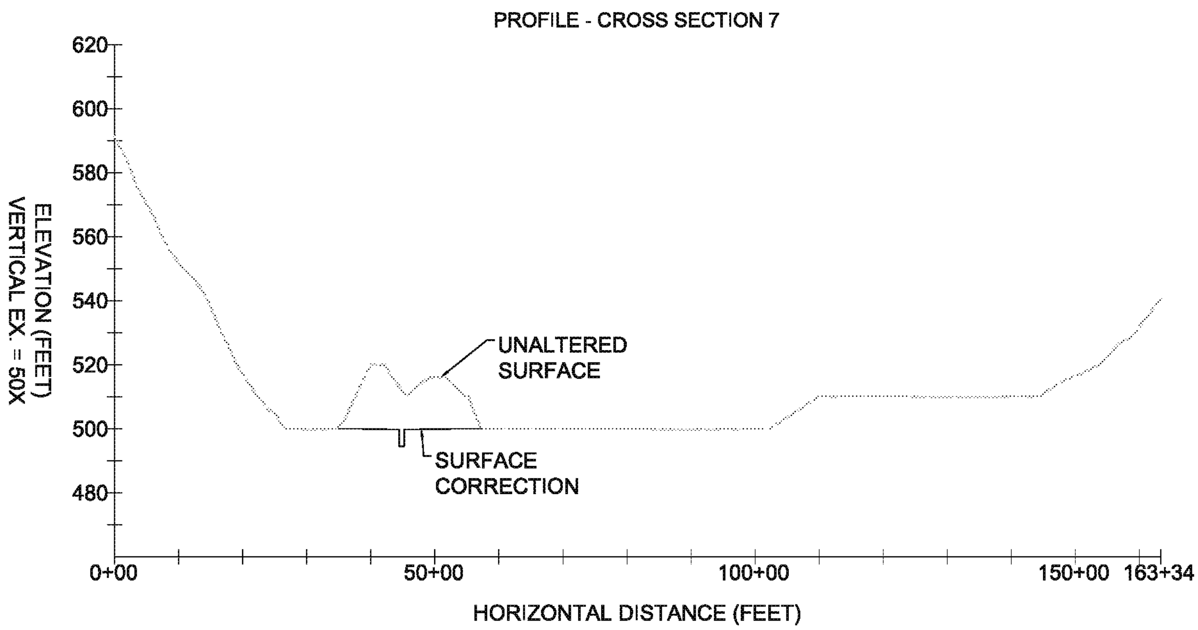
SRK JOB NO.: 73400.040

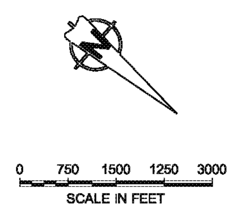
FILE NAME: Basins.dwg

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DATE:	APPROVED:	FIGURE:	REVISION NO.
JAN. 2010			0







SRK Consulting
Engineers and Scientists
1250 Lamoille Hwy, Suite 520
Elko, Nevada 89801
775-753-4151

SRK JOB NO.: 73400.040
FILE NAME: 073400.040bas.dwg

FIGURE 5

FAIRBANKS GOLD MINING, INC
FORT KNOX MINE

DAM BREAK INUNDATION ANALYSIS

EXAMPLE OF CROSS SECTION GEOMETRY MODIFICATION

DATE:	APPROVED:	FIGURE	REVISION NO.
FEB. 2010			1

K:_SITES\Fort Knox\073400.040- Ft Knox TSF Dam Break\040_AutoCAD\073400.040bas.dwg

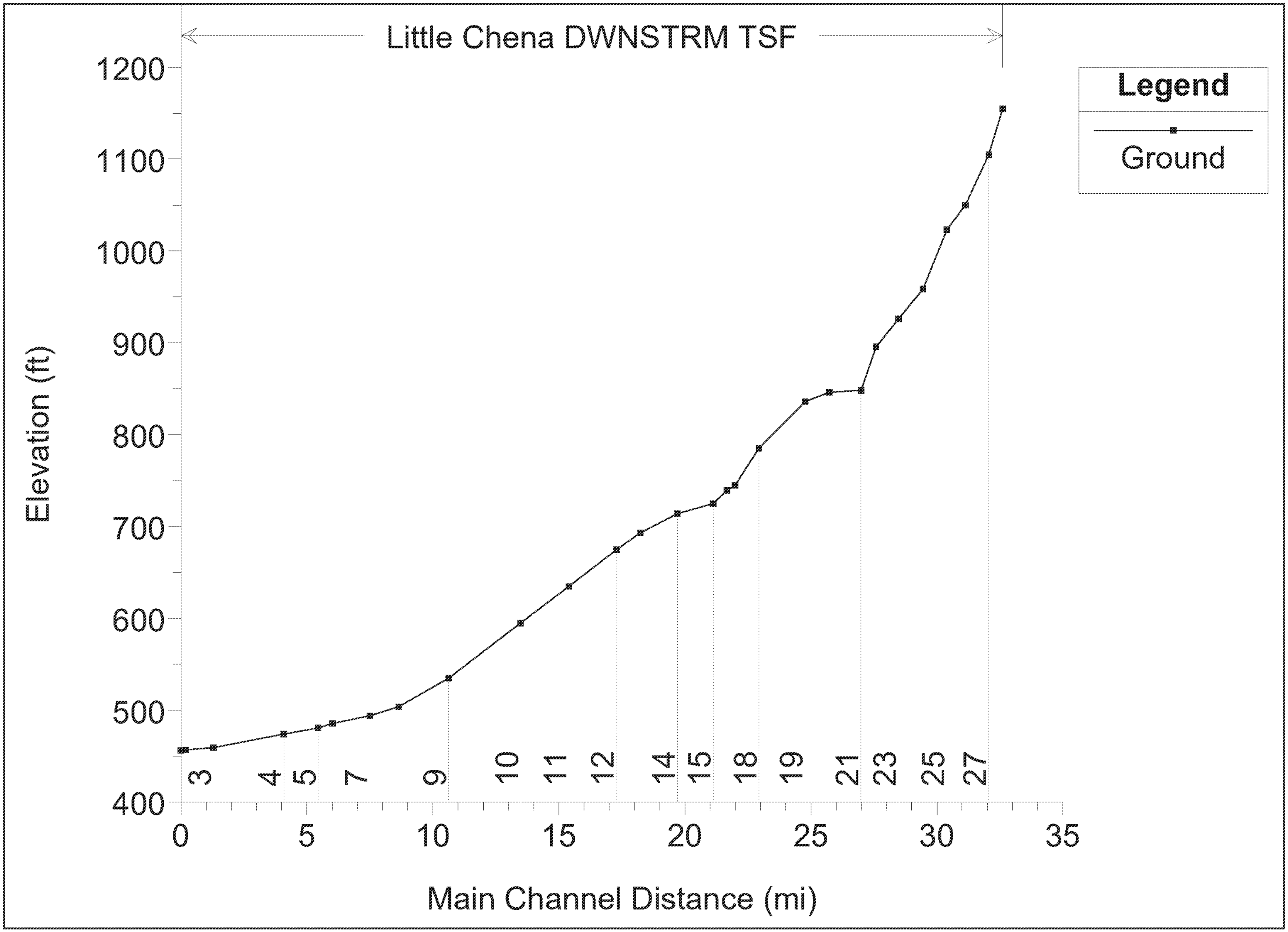


Figure 6: Study Reach Profile

Appendices

Appendix 1
Calculations for Shallow Breach of TSF

Table 1.1
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

Sample Calculation - Potential Solid Mobilization

Flood volume	10,219	acre-feet
	445,139,640	cf
Assume	50%	solids content in slurry
	13,888,357	tons solids
<u>If all solids are from dam:</u>		
Dam bulk density*	134.9	pcf
	0.0675	tons/cf
Amount removed	205,905,956.53	cf
<u>If all solids are from tailings:</u>		
Slimes bulk density*	76.6	pcf
	0.0383	tons/cf
Solids SG*	2.72	
Vol. water content	0.55	
Tailings volume	656,000,000	cf
Tailings solids	25,124,800	tons
Tailings pore water	359,940,422	cf
Free water	445,139,640	cf
Total water	805,080,062	cf
	25,118,498	tons
Solids content	50.0%	
Amount removed	656,000,000.00	cf

*(Knight Piésold 2009)

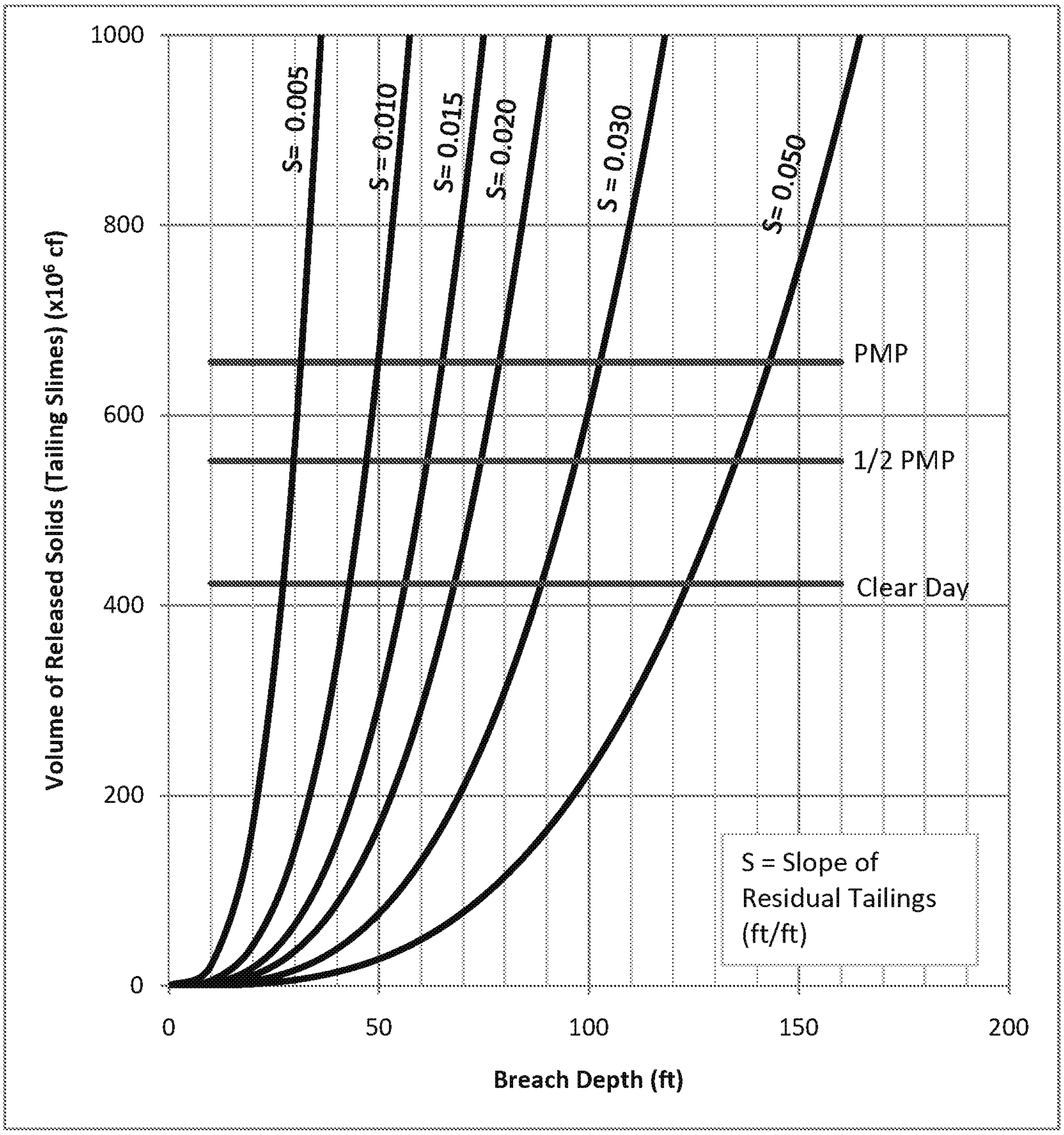


Figure 1.1: Volume of Released Solids (Tailing Slimes) vs Breach Depth

Appendix 2
Results for TSF Shallow Breach Scenarios

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

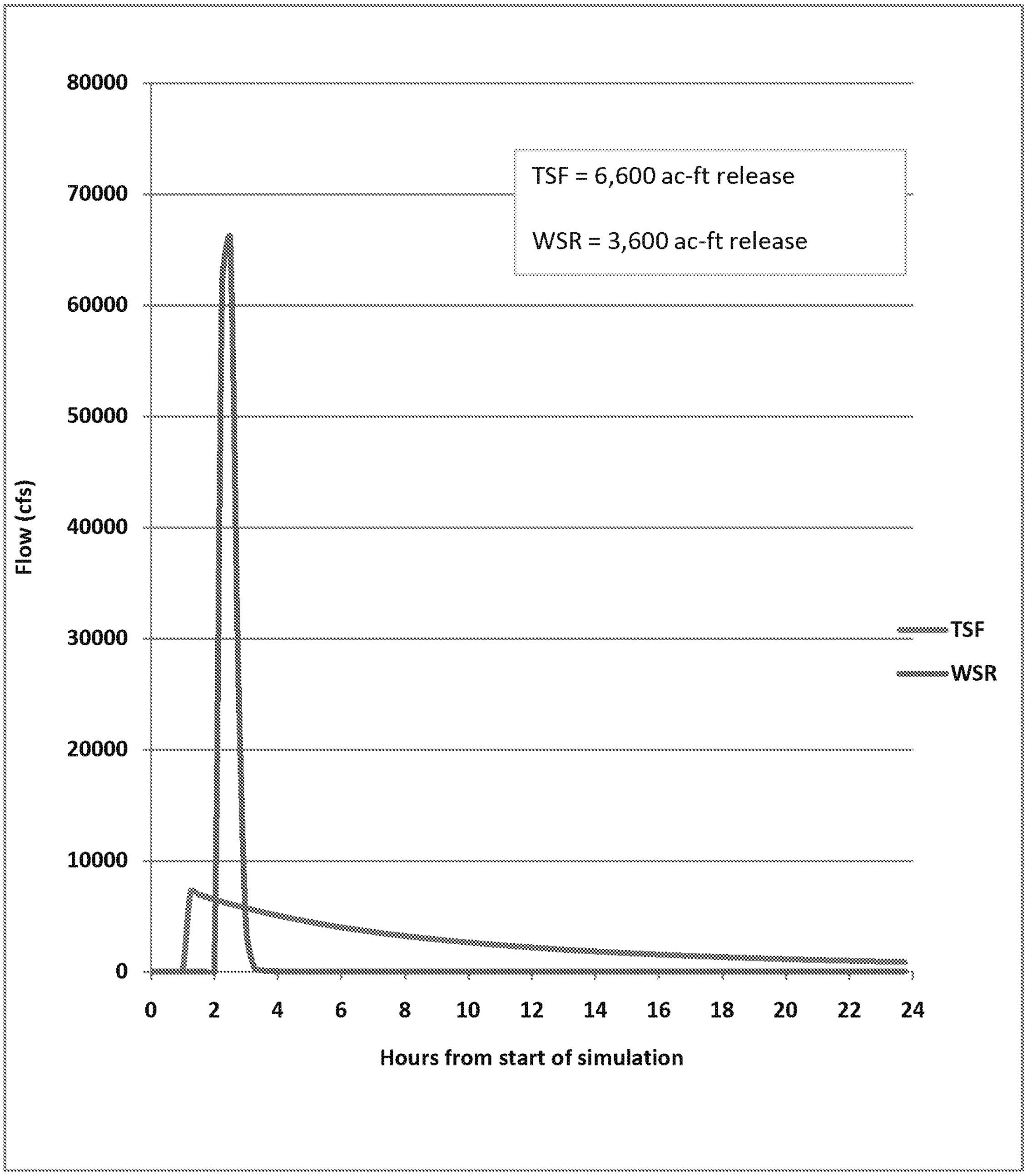


Figure 2.1: Dam Breach Hydrograph - Shallow Breach - Clear Day

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

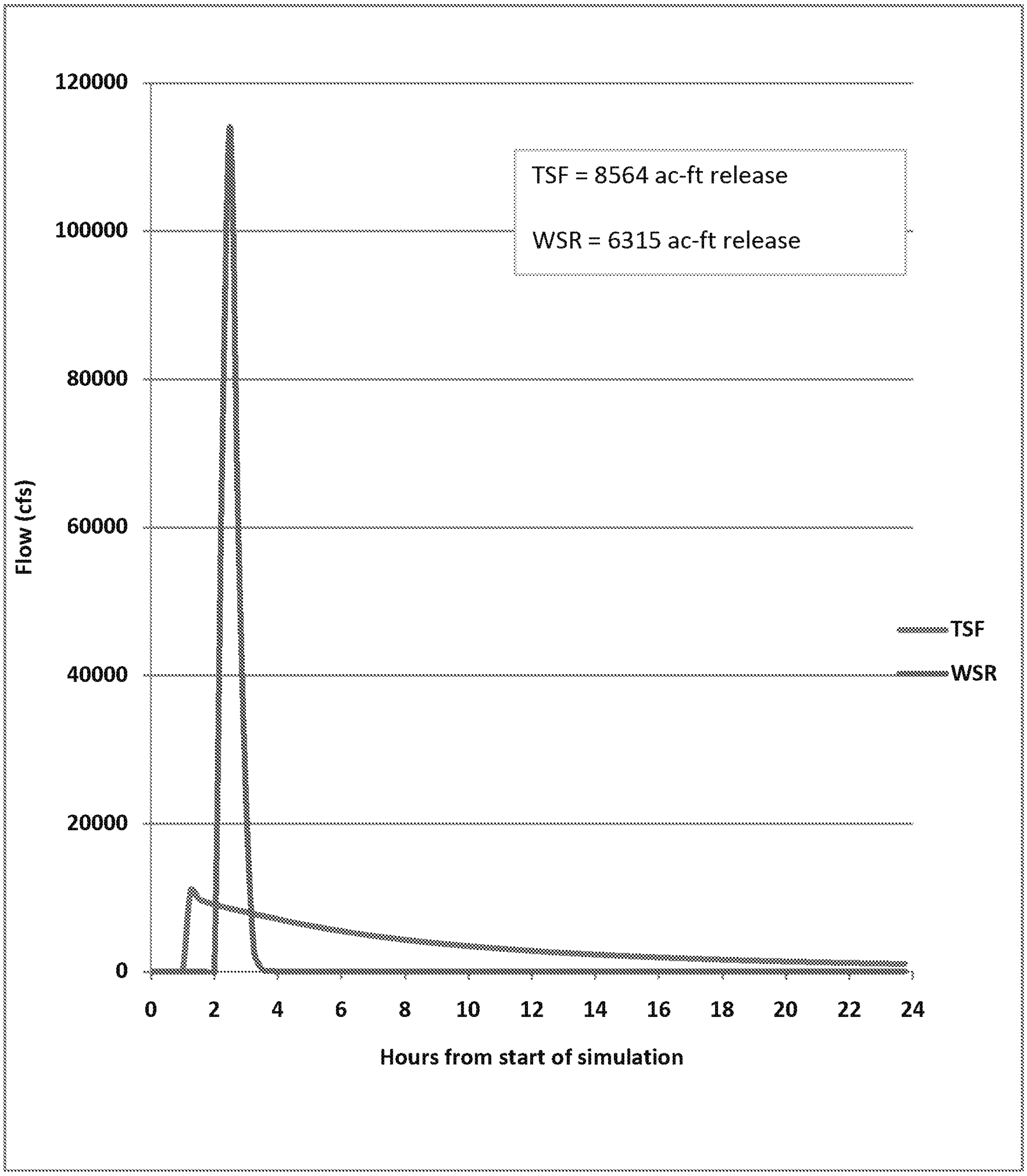


Figure 2.2: Dam Breach Hyrdograph - Shallow Breach - 1/2 PMP

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

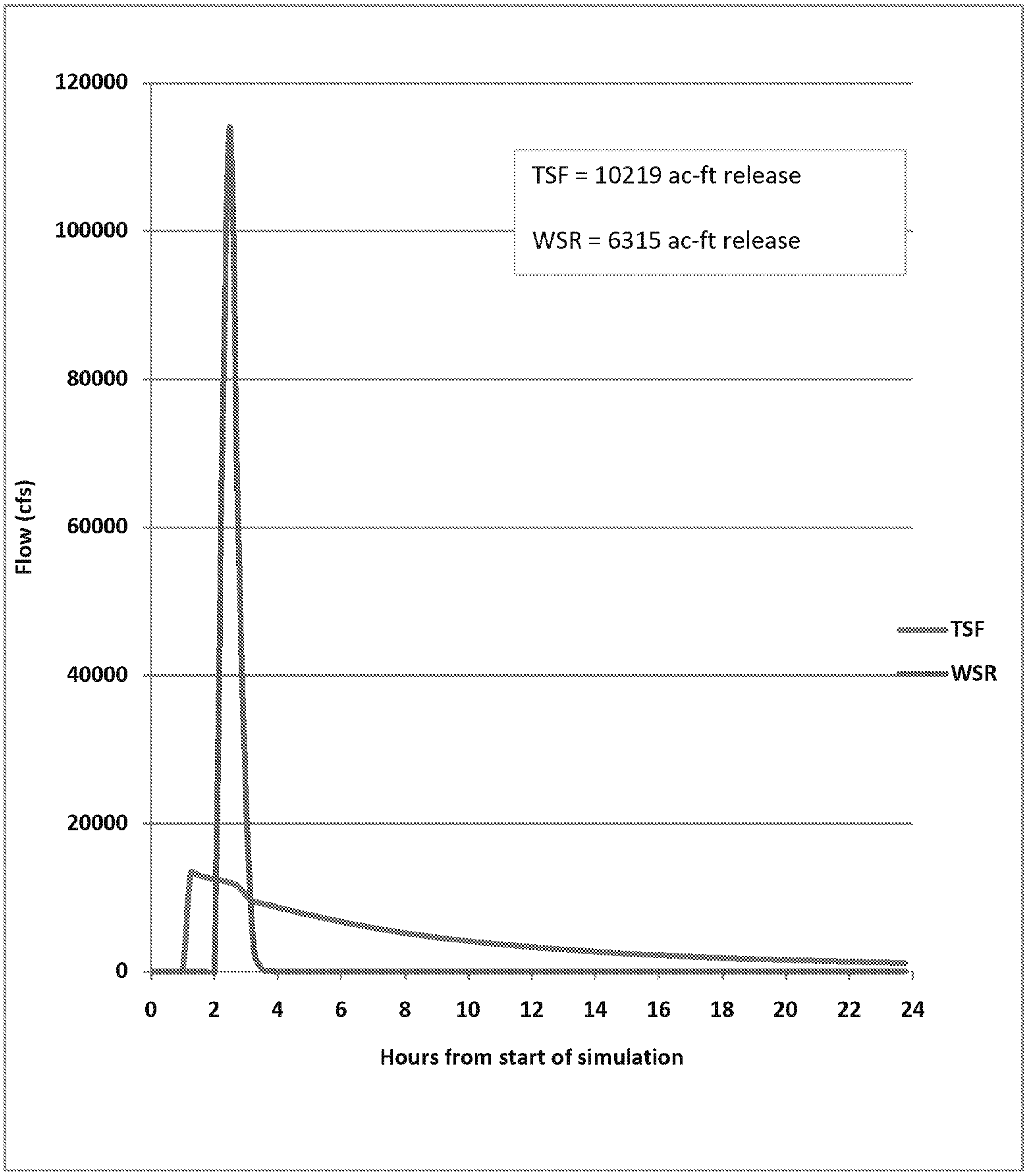


Figure 2.3: Dam Breach Hydrograph - Shallow Breach - PMP

Table 2.1
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Shallow Breach - Clear Day

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1164.2	7.6	250	7154	6904	2.8	7.6	4.8
27	0.6	1104.8	1106.8	1114.9	8.1	250	7072	6822	2.5	6.5	4.1
26	1.5	1049.8	1052.2	1060.4	8.2	250	6954	6704	2.1	5.6	3.5
25[2]	2.2	1023.1	1025.0	1038.4	13.4	250	6124	5874	2.6	0.7	-1.9
24	3.2	958.6	961.1	979.9	18.8	250	70781	70531	2.0	8.6	6.6
23	4.1	926.1	928.6	943.2	14.7	250	66643	66393	2.1	6.7	4.6
22	5.0	895.7	897.6	911.0	13.5	250	61567	61317	2.7	10.3	7.6
21	5.6	848.3	853.8	865.6	11.8	250	35901	35651	0.7	1.6	0.9
20	6.9	846.1	849.7	861.0	11.3	250	16832	16582	1.4	3.3	1.9
19	7.8	836.1	838.7	849.4	10.7	250	14933	14683	1.9	5.3	3.4
18	9.7	785.2	787.5	797.5	10.1	250	14401	14151	2.2	6.4	4.2
17	10.6	745.0	748.0	757.9	9.9	250	14264	14014	1.7	4.5	2.8
16	10.9	739.4	742.0	750.6	8.6	250	14176	13926	1.9	4.8	2.9
15[3]	11.5	725.0	728.9	735.2	6.3	250	12003	11753	1.3	1.5	0.2
14	12.9	714.0	717.2	725.4	8.2	250	10318	10068	1.6	3.9	2.3
13	14.4	693.3	696.2	700.9	4.7	250	10135	9885	1.7	3.0	1.2
12	15.3	674.9	677.7	682.9	5.2	250	9977	9727	1.8	3.4	1.6
11	17.2	634.8	637.0	641.4	4.4	250	9482	9232	1.7	2.8	1.1
10	19.1	595.0	597.8	603.2	5.4	250	8863	8613	1.8	3.4	1.7
9	22.0	534.9	538.0	542.8	4.8	250	8130	7880	1.6	2.9	1.3
8	24.0	503.9	507.7	511.4	3.7	250	7175	6925	1.3	2.0	0.7
7	25.1	494.1	498.3	501.2	2.9	250	6611	6361	1.2	1.9	0.7
6[4]	26.6	485.7	487.2	490.2	3.0	250	6042	5792	0.9	1.6	0.7
5	27.2	480.7	483.0	486.1	3.1	250	5810	5560	0.8	1.4	0.6
4	28.5	474.1	476.6	479.7	3.0	250	5267	5017	1.0	1.4	0.5
3	31.3	459.3	462.8	466.4	3.6	250	4450	4200	0.7	1.2	0.6
2	32.4	456.9	460.8	464.7	3.9	250	3810	3560	0.6	0.7	0.1
1[5]	32.6	456.3	460.3	464.4	4.1	250	3809	3559	0.9	1.5	0.6

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 2.2
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Shallow Breach - 1/2 PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1165.7	9.1	250	10899	10649	2.8	8.5	5.7
27	0.6	1104.8	1106.87	1116.5	9.6	257.91	10629	10371	2.5	7.2	4.7
26	1.5	1049.8	1052.24	1061.7	9.5	257.56	10208	9951	2.1	6.2	4.1
25[2]	2.2	1023.1	1025.08	1042.2	17.2	252.77	7533	7280	2.6	0.6	-2.0
24	3.2	958.6	962.97	983.76	20.8	554.19	112768	112214	2.5	9.8	7.2
23	4.1	926.1	931.46	946.56	15.1	1704.42	106095	104391	2.9	7.6	4.7
22	5.0	895.7	902.08	913.51	11.4	2272.35	100052	97780	5.6	11.4	5.8
21	5.6	848.3	862.31	869.38	7.1	6412.47	59550	53137	0.5	1.8	1.3
20	6.9	846.1	859.66	864.44	4.8	11718.6	33867	22148	3.0	3.7	0.6
19	7.8	836.1	848.54	852.74	4.2	11983.4	30125	18142	5.1	6.2	1.1
18	9.7	785.2	797.11	800.33	3.2	12743.7	28691	15947	6.3	7.4	1.1
17	10.6	745.0	757.62	761.4	3.8	13110.6	28267	15156	4.4	5.6	1.2
16	10.9	739.4	753.43	755.21	1.8	3347.41	12145	8798	0.7	2.0	1.3
15[3]	11.5	725.0	744.78	745.94	1.2	62979.6	72374	9395	2.1	2.2	0.1
14	12.9	714.0	734.98	736.11	1.1	60569.2	70300	9731	6.4	6.7	0.3
13	14.4	693.3	705.18	705.78	0.6	60484.1	70317	9833	3.9	4.0	0.1
12	15.3	674.9	687.57	688.22	0.6	60284.3	70109	9825	4.4	4.5	0.1
11	17.2	634.8	645.79	646.39	0.6	62377.4	72420	10042	3.7	3.8	0.1
10	19.1	595.0	610.07	610.89	0.8	68206.1	78939	10733	5.2	5.4	0.2
9	22.0	534.9	548.77	549.48	0.7	67766.4	78976	11209	4.4	4.6	0.2
8	24.0	503.9	516.64	517.31	0.7	66427.7	78683	12256	3.1	3.2	0.1
7	25.1	494.1	505.66	506.39	0.7	63653	76721	13068	2.4	2.4	0.1
6[4]	26.6	485.7	496.05	496.84	0.8	62725.4	76565	13840	2.8	2.9	0.1
5	27.2	480.7	492.15	492.99	0.8	60055.9	73847	13791	2.3	2.4	0.1
4	28.5	474.1	485.62	486.44	0.8	55955	69112	13157	2.3	2.4	0.1
3	31.3	459.3	473.2	474.06	0.9	46849.3	57278	10429	1.7	1.8	0.1
2	32.4	456.9	471.23	472.04	0.8	45588.8	55814	10225	1.5	1.6	0.1
1[5]	32.6	456.3	470.78	471.57	0.8	45585.5	55815	10229	2.1	2.2	0.1

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 2.3
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Shallow Breach - PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1166.5	9.9	250	13252	13002	2.8	8.8	6.1
27	0.6	1104.8	1106.87	1117.5	10.6	257.91	13160	12902	2.5	7.6	5.1
26	1.5	1049.8	1052.24	1062.7	10.4	257.56	13029	12772	2.1	6.5	4.4
25[2]	2.2	1023.1	1025.08	1042.5	17.4	252.77	10618	10366	2.6	0.8	-1.8
24	3.2	958.6	964.14	984.1	19.9	857.94	116220	115362	3.0	9.8	6.8
23	4.1	926.1	932.46	946.8	14.4	3158.6	109725	106567	3.2	7.6	4.5
22	5.0	895.7	903.25	913.7	10.5	4406.4	103940	99533	6.2	11.5	5.3
21	5.6	848.3	866.29	869.8	3.5	13954	61915	47960	0.6	1.8	1.2
20	6.9	846.1	863.45	864.9	1.4	26700	34272	7573	3.3	3.5	0.2
19	7.8	836.1	852.27	853.6	1.3	27382	35098	7717	6.1	6.4	0.3
18	9.7	785.2	800.41	801.5	1.1	29175	37138	7963	7.4	7.7	0.3
17	10.6	745.0	762.25	764.0	1.8	30050	38027	7977	5.4	5.7	0.3
16	10.9	739.4	759.43	761.0	1.6	9631	21019	11388	1.0	1.9	0.9
15[3]	11.5	725.0	751.82	752.8	1.0	129919	142914	12995	2.7	2.8	0.1
14	12.9	714.0	741.15	742.1	0.9	127608	141254	13645	8.0	8.2	0.2
13	14.4	693.3	708.74	709.4	0.6	127757	141656	13899	4.6	4.7	0.1
12	15.3	674.9	691.36	692.0	0.7	127350	141433	14083	5.2	5.3	0.1
11	17.2	634.8	649.44	650.1	0.6	132523	146961	14438	4.4	4.5	0.1
10	19.1	595.0	615.19	616.0	0.8	147427	162711	15284	6.3	6.5	0.2
9	22.0	534.9	553.04	553.7	0.7	147749	163372	15623	5.4	5.5	0.1
8	24.0	503.9	520.6	521.3	0.7	145311	161835	16524	3.8	3.8	0.0
7	25.1	494.1	509.83	510.4	0.6	139194	153987	14793	2.6	3.1	0.6
6[4]	26.6	485.7	499.64	500.2	0.6	141277	157031	15754	3.4	3.4	0.0
5	27.2	480.7	495.84	496.5	0.6	136027	152573	16546	2.8	2.8	0.1
4	28.5	474.1	489.22	489.9	0.6	127266	144247	16981	2.8	2.9	0.1
3	31.3	459.3	477.11	477.8	0.7	105616	118936	13320	2.0	2.1	0.1
2	32.4	456.9	474.94	475.6	0.6	103748	116842	13094	1.9	2.0	0.1
1[5]	32.6	456.3	474.44	475.1	0.6	103767	116863	13096	2.5	2.6	0.1

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 2.4
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Shallow Breach - Local 1/2 PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1165.7	9.1	250	10899	10649	2.8	8.5	5.6
27	0.6	1104.8	1106.8	1116.5	9.7	250	10629	10379	2.5	7.2	4.7
26	1.5	1049.8	1052.2	1061.7	9.5	250	10208	9958	2.1	6.2	4.1
25[2]	2.2	1023.1	1025.0	1042.2	17.2	250	7533	7283	2.6	0.6	-2.0
24	3.2	958.6	961.1	983.8	22.7	250	112768	112518	2.0	9.8	7.7
23	4.1	926.1	928.6	946.6	18.0	250	106072	105822	2.1	7.5	5.5
22	5.0	895.7	897.6	913.5	16.0	250	100048	99798	2.7	11.4	8.7
21	5.6	848.3	853.8	869.4	15.6	250	59446	59196	0.7	1.8	1.1
20	6.9	846.1	849.7	864.4	14.8	250	33865	33615	1.4	3.7	2.3
19	7.8	836.1	838.7	852.7	14.0	250	30116	29866	1.9	6.2	4.3
18	9.7	785.2	787.5	800.3	12.9	250	28654	28404	2.2	7.4	5.2
17	10.6	745.0	748.0	761.4	13.4	250	28211	27961	1.7	5.6	3.9
16	10.9	739.4	742.0	753.6	11.5	250	27998	27748	1.9	5.8	3.9
15[3]	11.5	725.0	728.9	737.6	8.7	250	22406	22156	1.3	1.7	0.4
14	12.9	714.0	717.2	727.9	10.6	250	18793	18543	1.6	4.5	2.9
13	14.4	693.3	696.2	701.9	5.7	250	18384	18134	1.7	3.2	1.4
12	15.3	674.9	677.7	684.0	6.3	250	18067	17817	1.8	3.6	1.9
11	17.2	634.8	637.0	642.3	5.3	250	17067	16817	1.7	2.9	1.2
10	19.1	595.0	597.8	604.5	6.7	250	15762	15512	1.8	3.7	2.0
9	22.0	534.9	538.0	543.9	5.9	250	14309	14059	1.6	3.2	1.6
8	24.0	503.9	507.7	512.2	4.6	250	12636	12386	1.3	2.2	0.9
7	25.1	494.1	498.3	501.8	3.5	250	11367	11117	1.2	1.9	0.7
6[4]	26.6	485.7	487.2	491.0	3.8	250	9759	9509	0.9	1.8	0.9
5	27.2	480.7	483.0	486.9	3.9	250	9174	8924	0.8	1.5	0.7
4	28.5	474.1	476.6	480.4	3.8	250	8158	7908	1.0	1.6	0.6
3	31.3	459.3	462.8	467.2	4.4	250	6470	6220	0.7	1.2	0.6
2	32.4	456.9	460.8	465.6	4.8	250	5961	5711	0.6	0.8	0.2
1[5]	32.6	456.3	460.3	465.2	4.9	250	5959	5709	0.9	1.6	0.7

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 2.5
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Shallow Breach - Local PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1166.5	9.9	250	13252	13002	2.8	8.8	6.0
27	0.6	1104.8	1106.8	1117.5	10.6	250	13160	12910	2.5	7.6	5.1
26	1.5	1049.8	1052.2	1062.7	10.5	250	13029	12779	2.1	6.5	4.5
25[2]	2.2	1023.1	1025.0	1042.5	17.4	250	10725	10475	2.6	0.8	-1.8
24	3.2	958.6	961.1	984.1	23.0	250	116243	115993	2.0	9.8	7.8
23	4.1	926.1	928.6	946.8	18.3	250	109748	109498	2.1	7.6	5.6
22	5.0	895.7	897.6	913.7	16.2	250	103935	103685	2.7	11.5	8.8
21	5.6	848.3	853.8	869.8	16.0	250	61968	61718	0.7	1.8	1.1
20	6.9	846.1	849.7	864.9	15.2	250	36458	36208	1.4	3.7	2.3
19	7.8	836.1	838.7	853.2	14.4	250	32595	32345	1.9	6.3	4.4
18	9.7	785.2	787.5	800.7	13.2	250	31077	30827	2.2	7.4	5.2
17	10.6	745.0	748.0	761.9	13.9	250	30600	30350	1.7	5.7	4.1
16	10.9	739.4	742.0	754.0	12.0	250	30379	30129	1.9	6.0	4.1
15[3]	11.5	725.0	728.9	738.0	9.1	250	24098	23848	1.3	1.7	0.4
14	12.9	714.0	717.2	728.3	11.0	250	20484	20234	1.6	4.6	3.1
13	14.4	693.3	696.2	702.1	5.9	250	20064	19814	1.7	3.2	1.5
12	15.3	674.9	677.7	684.2	6.5	250	19723	19473	1.8	3.7	1.9
11	17.2	634.8	637.0	642.5	5.5	250	18805	18555	1.7	3.0	1.3
10	19.1	595.0	597.8	604.8	6.9	250	17413	17163	1.8	3.8	2.1
9	22.0	534.9	538.0	544.1	6.1	250	15746	15496	1.6	3.3	1.7
8	24.0	503.9	507.7	512.4	4.7	250	13972	13722	1.3	2.2	0.9
7	25.1	494.1	498.3	501.9	3.6	250	12671	12421	1.2	1.9	0.7
6[4]	26.6	485.7	487.2	491.3	4.0	250	11005	10755	0.9	1.8	0.9
5	27.2	480.7	483.0	487.1	4.1	250	10348	10098	0.8	1.6	0.8
4	28.5	474.1	476.6	480.7	4.0	250	9235	8985	1.0	1.6	0.6
3	31.3	459.3	462.8	467.4	4.6	250	7313	7063	0.7	1.3	0.6
2	32.4	456.9	460.8	465.8	5.0	250	6677	6427	0.6	0.8	0.2
1[5]	32.6	456.3	460.3	465.4	5.1	250	6675	6425	0.9	1.6	0.7

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 2.6
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis
PMP Solids Deposition Analysis

River Station	Distance from TSF	Max. Flow Area	Reach Length	Volume	Cul. Volume	Deposition in Reach	Deposition Only in Reaches with 0.5% Slope	Deposition across Half of Inundation Area with 0.5% Slope Reaches
	(mi)	(sf)	(ft)	($x10^6$ cf)	($x10^6$ cf)	($x10^6$ cf)	($x10^6$ cf)	($x10^6$ cf)
28	0.6	2381	2919	0	0	656	656	656
27	1.5	2698	4892	7.4	7.4	648.3		
26	2.2	3242	3868	14.5	21.9	633.8		
25	3.2	19504	5003	44.0	65.9	589.8		
24	4.1	17993	5133	93.8	159.7	496.0		
23	5.0	20937	4687	99.9	259.6	396.1	555.8	605.7
22	5.6	14985	3171	84.2	343.8	311.9	471.6	563.7
21	6.9	51066	6657	104.7	448.6	207.1	366.9	511.3
20	7.8	16364	5045	224.4	673.0	0.0	142.4	399.1
19	9.7	9250	9697	64.6	737.6		77.8	366.8
18	10.6	7516	4995	81.3	818.9		0.0	326.1
17	10.9	7954	1685	38.6	857.5			306.8
16	11.5	7948	2876	13.4	870.9			300.1
15	12.9	21394	7526	42.2	913.1			279.0
14	14.4	7104	7731	107.2	1020.4			225.4
13	15.3	12589	4999	76.1	1096.5			187.3
12	17.2	11133	10029	59.3	1155.8			157.7
11	19.1	12295	10132	117.5	1273.3			98.9
10	22.0	8420	15042	104.9	1378.2			46.5
9	24.0	9250	10462	132.9	1511.1			0.0
8	25.1	13511	6053	119.1	1630.2			
7	26.6	16387	7802	90.5	1720.6			
6	27.2	11842	3053	110.1	1830.8			
5	28.5	14044	7161	39.5	1870.3			
4	31.3	12774	14732	96.0	1966.3			
3	32.4	13613	5795	194.4	2160.7			
2	32.6	19625	1032	96.3	2257.0			
1	32.6	11276	0	15.9	2272.9			

Appendix 3
Results for TSF Deep Breach Scenarios

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

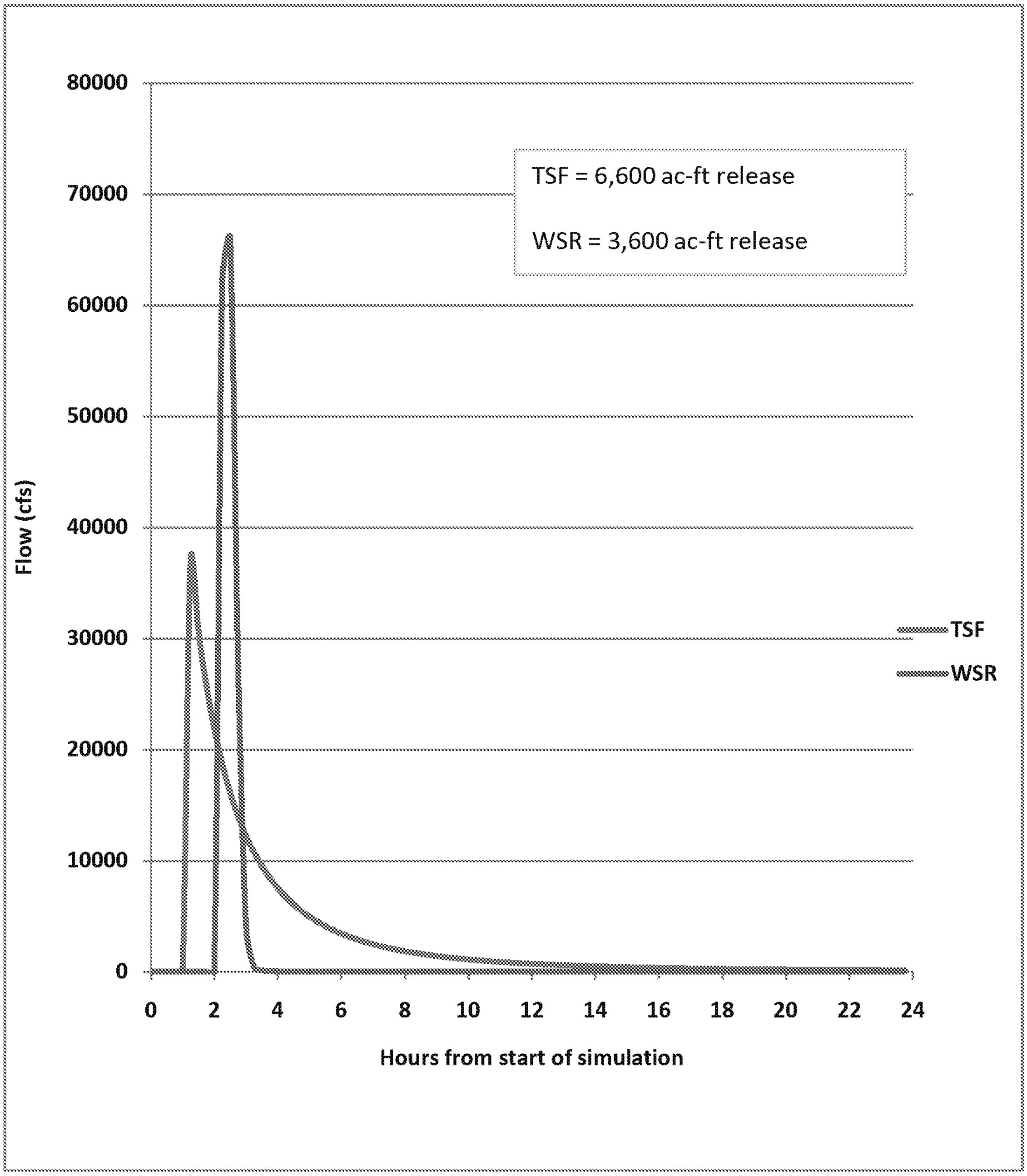


Figure 3.1: Dam Breach Hydrograph - Deep Breach - Clear Day

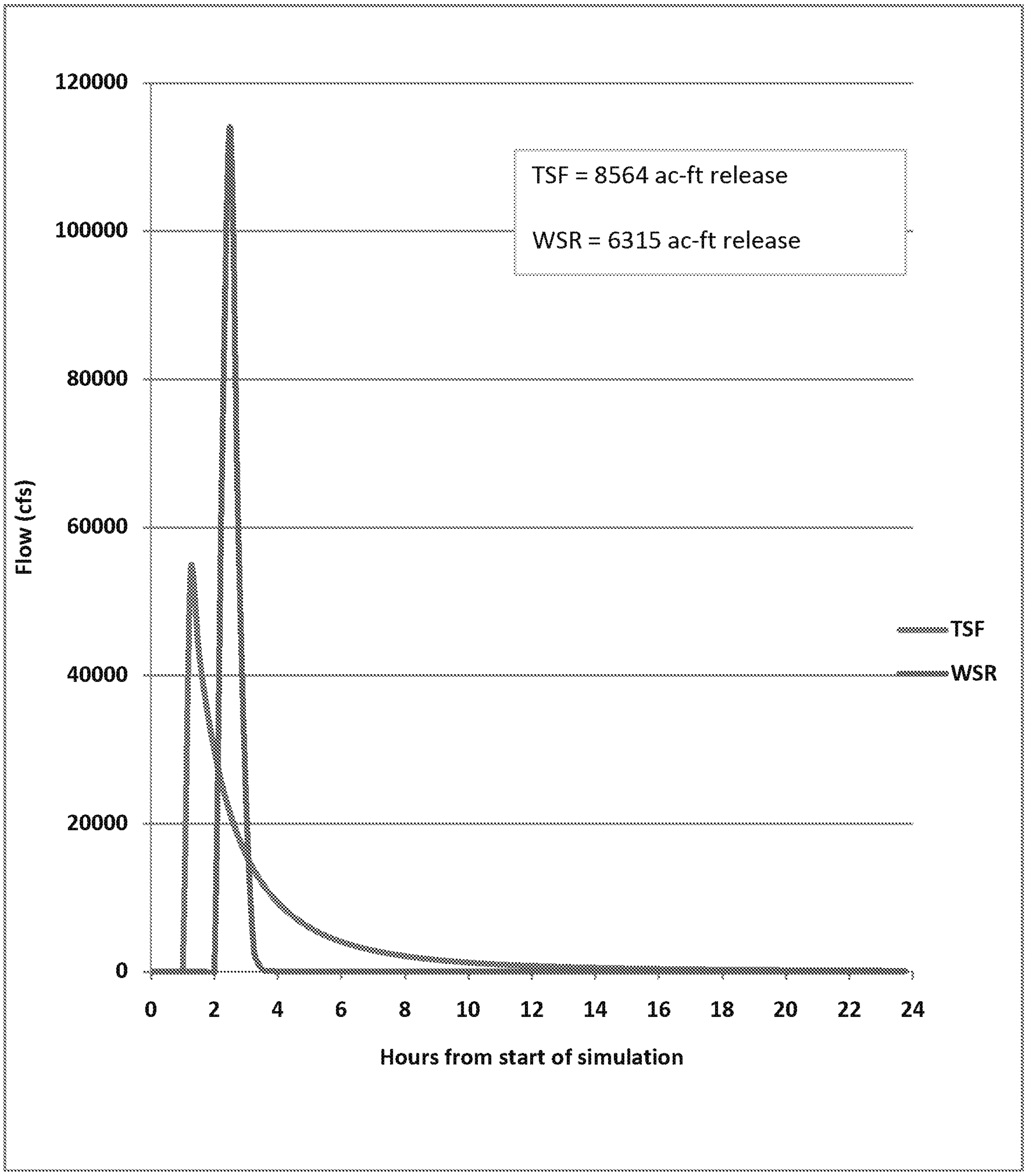


Figure 3.2: Dam Breach Hydrograph - Deep Breach - 1/2 PMP

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

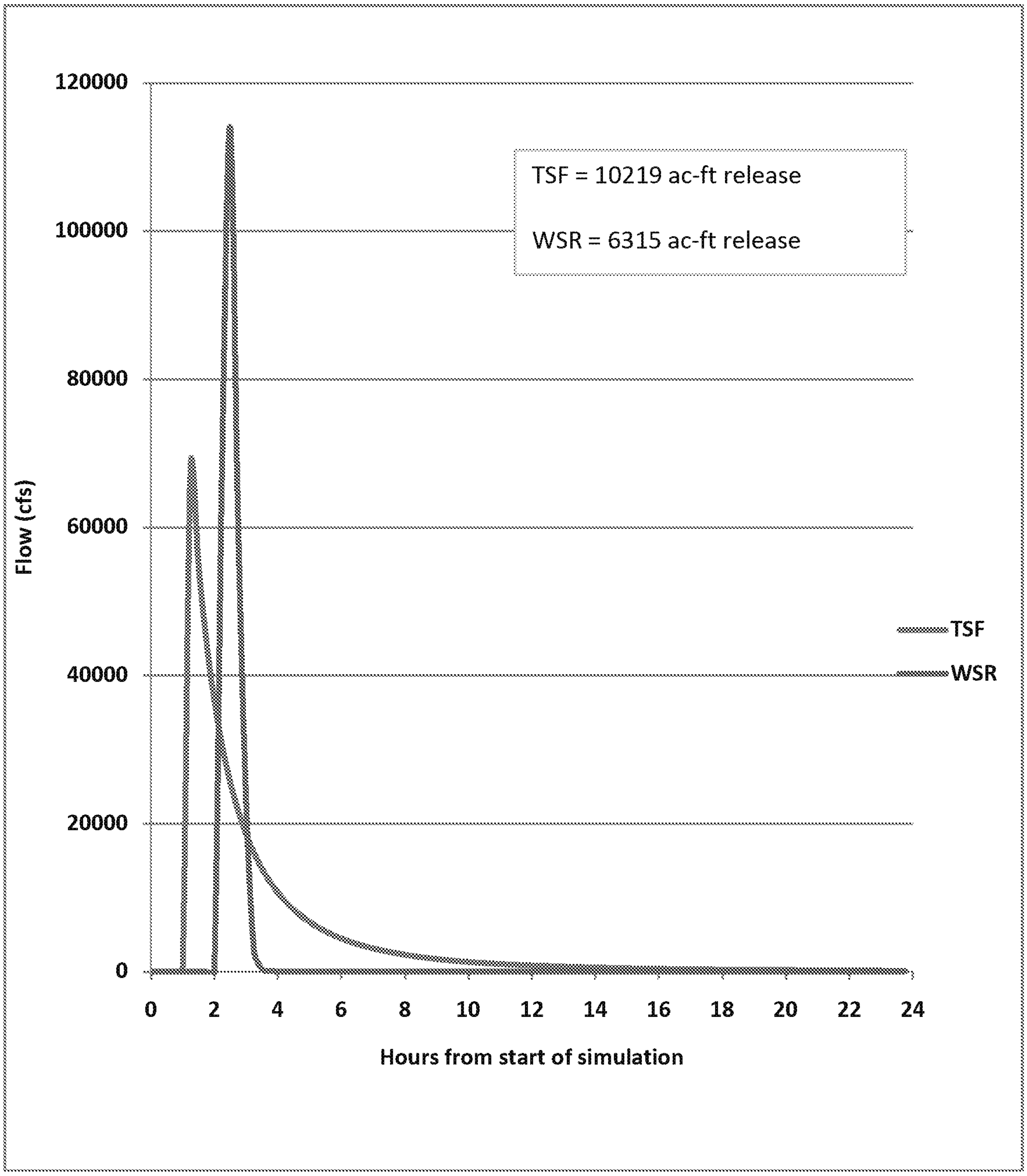


Figure 3.3: Dam Breach Hydrograph - Deep Breach - PMP

Table 3.1

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Deep Breach - Clear Day

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1171.7	15.1	250	36619	36369	2.8	11.3	8.5
27	0.6	1104.8	1106.8	1123.1	16.3	250	35299	35049	2.5	9.8	7.3
26	1.5	1049.8	1052.2	1067.5	15.3	250	33590	33340	2.1	8.5	6.4
25[2]	2.2	1023.1	1025.0	1039.6	14.6	250	20898	20648	2.6	2.1	-0.5
24	3.2	958.6	961.1	981.5	20.4	250	86350	86100	2.0	9.0	7.0
23	4.1	926.1	928.6	944.8	16.3	250	83922	83672	2.1	7.0	5.0
22	5.0	895.7	897.6	912.4	14.8	250	81193	80943	2.7	10.9	8.2
21	5.6	848.3	853.8	868.5	14.7	250	50816	50566	0.7	1.7	1.0
20	6.9	846.1	849.7	863.8	14.1	250	29965	29715	1.4	3.6	2.2
19	7.8	836.1	838.7	852.2	13.4	250	26925	26675	1.9	6.1	4.2
18	9.7	785.2	787.5	799.9	12.4	250	25888	25638	2.2	7.2	5.0
17	10.6	745.0	748.0	760.8	12.8	250	25559	25309	1.7	5.4	3.8
16	10.9	739.4	742.0	753.1	11.1	250	25408	25158	1.9	5.7	3.8
15[3]	11.5	725.0	728.9	737.4	8.5	250	20717	20467	1.3	1.6	0.4
14	12.9	714.0	717.2	727.6	10.4	250	17974	17724	1.6	4.5	2.9
13	14.4	693.3	696.2	701.8	5.6	250	17662	17412	1.7	3.1	1.4
12	15.3	674.9	677.7	683.9	6.2	250	17420	17170	1.8	3.6	1.9
11	17.2	634.8	637.0	642.3	5.3	250	16582	16332	1.7	2.9	1.2
10	19.1	595.0	597.8	604.5	6.6	250	15435	15185	1.8	3.7	2.0
9	22.0	534.9	538.0	543.9	5.9	250	14062	13812	1.6	3.2	1.6
8	24.0	503.9	507.7	512.2	4.5	250	12430	12180	1.3	2.2	0.9
7	25.1	494.1	498.3	501.8	3.5	250	11150	10900	1.2	1.9	0.7
6[4]	26.6	485.7	487.2	491.0	3.8	250	9501	9251	0.9	1.8	0.9
5	27.2	480.7	483.0	486.8	3.9	250	8900	8650	0.8	1.5	0.7
4	28.5	474.1	476.6	480.4	3.7	250	7855	7605	1.0	1.6	0.6
3	31.3	459.3	462.8	467.1	4.3	250	6408	6158	0.7	1.3	0.6
2	32.4	456.9	460.8	465.4	4.6	250	5591	5341	0.6	0.8	0.2
1[5]	32.6	456.3	460.3	465.1	4.8	250	5588	5338	0.9	1.6	0.7

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 3.2

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Deep Breach - 1/2 PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1174.2	17.6	250	53318.9	53069	2.77	12.34	9.6
27	0.6	1104.8	1106.87	1126	19.1	257.91	51361.3	51103	2.49	10.8	8.3
26	1.5	1049.8	1052.24	1070.1	17.8	257.56	48906.9	48649	2.11	9.52	7.4
25[2]	2.2	1023.1	1025.08	1043.5	18.5	252.77	24855.5	24603	2.56	1.66	-0.9
24	3.2	958.6	962.97	985.33	22.4	554.19	132200	131646	2.54	10.18	7.6
23	4.1	926.1	931.46	948.07	16.6	1704.42	126535	124831	2.85	7.91	5.1
22	5.0	895.7	902.08	914.78	12.7	2272.35	122250	119977	5.59	11.94	6.4
21	5.6	848.3	862.31	872.71	10.4	6412.47	78087.2	71675	0.49	1.78	1.3
20	6.9	846.1	859.66	867.63	8.0	11718.6	55018.3	43300	3.03	4.12	1.1
19	7.8	836.1	848.54	855.72	7.2	11983.4	49986.9	38003	5.1	6.95	1.9
18	9.7	785.2	797.11	802.84	5.7	12743.7	47640.3	34897	6.27	8.05	1.8
17	10.6	745.0	757.62	764.72	7.1	13110.6	46871	33760	4.35	6.6	2.3
16	10.9	739.4	753.43	756.34	2.9	3347.41	46579.4	43232	0.71	6.75	6.0
15[3]	11.5	725.0	744.78	745.92	1.1	62979.6	72202.5	9223	2.11	2.21	0.1
14	12.9	714.0	734.98	736.08	1.1	60569.2	70041.4	9472	6.41	6.69	0.3
13	14.4	693.3	705.18	705.76	0.6	60484.1	70039.5	9555	3.88	4	0.1
12	15.3	674.9	687.57	688.2	0.6	60284.3	69803.6	9519	4.38	4.51	0.1
11	17.2	634.8	645.79	646.37	0.6	62377.4	72140.4	9763	3.67	3.79	0.1
10	19.1	595.0	610.07	610.87	0.8	68206.1	78700.6	10494	5.17	5.36	0.2
9	22.0	534.9	548.77	549.47	0.7	67766.4	78753.7	10987	4.42	4.58	0.2
8	24.0	503.9	516.64	517.3	0.7	66427.7	78512.3	12085	3.06	3.17	0.1
7	25.1	494.1	505.66	506.4	0.7	63653	76756.8	13104	2.37	2.43	0.1
6[4]	26.6	485.7	496.05	496.9	0.8	62725.4	77339.1	14614	2.77	2.9	0.1
5	27.2	480.7	492.15	493.08	0.9	60055.9	75192.4	15136	2.28	2.39	0.1
4	28.5	474.1	485.62	486.57	0.9	55955	71186.1	15231	2.32	2.44	0.1
3	31.3	459.3	473.2	474.23	1.0	46849.3	59528.6	12679	1.71	1.8	0.1
2	32.4	456.9	471.23	472.21	1.0	45588.8	58047.3	12459	1.48	1.6	0.1
1[5]	32.6	456.3	470.78	471.74	1.0	45585.5	58051.6	12466	2.13	2.23	0.1

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 3.3

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Deep Breach - PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1176.05	19.5	250	67365	67115	2.77	13.09	10.3
27	0.6	1104.8	1106.87	1128.03	21.2	257.91	64889	64631	2.49	11.51	9.0
26	1.5	1049.8	1052.24	1071.88	19.6	257.56	61932	61674	2.11	10.16	8.1
25[2]	2.2	1023.1	1025.08	1043.9	18.8	252.77	30371	30119	2.56	1.96	-0.6
24	3.2	958.6	964.14	985.78	21.6	857.94	138047	137189	2.98	10.3	7.3
23	4.1	926.1	932.46	948.49	16.0	3158.6	132557	129398	3.17	8.02	4.9
22	5.0	895.7	903.25	915.12	11.9	4406.4	128458	124051	6.23	12.09	5.9
21	5.6	848.3	866.29	873.67	7.4	13954	83868	69914	0.58	1.79	1.2
20	6.9	846.1	863.45	868.56	5.1	26700	61993	35294	3.33	4.24	0.9
19	7.8	836.1	852.27	856.57	4.3	27382	56791	29409	6.09	7.15	1.1
18	9.7	785.2	800.41	803.6	3.2	29175	54207	25032	7.37	8.26	0.9
17	10.6	745.0	762.25	765.69	3.4	30050	53350	23301	5.4	6.91	1.5
16	10.9	739.4	759.43	760.83	1.4	9631	19137	9506	1.01	1.77	0.8
15[3]	11.5	725.0	751.82	752.65	0.8	129919	141230	11311	2.74	2.79	0.0
14	12.9	714.0	741.15	741.95	0.8	127608	139345	11736	8.02	8.2	0.2
13	14.4	693.3	708.74	709.27	0.5	127757	139678	11920	4.61	4.71	0.1
12	15.3	674.9	691.36	691.93	0.6	127350	139415	12065	5.19	5.32	0.1
11	17.2	634.8	649.44	650	0.6	132523	144963	12440	4.38	4.48	0.1
10	19.1	595.0	615.19	615.91	0.7	147427	160771	13344	6.34	6.49	0.2
9	22.0	534.9	553.04	553.66	0.6	147749	161416	13668	5.39	5.51	0.1
8	24.0	503.9	520.6	521.23	0.6	145311	159924	14613	3.8	3.8	0.0
7	25.1	494.1	509.83	510.39	0.6	139194	152836	13643	2.56	3.12	0.6
6[4]	26.6	485.7	499.64	500.24	0.6	141277	156811	15534	3.35	3.37	0.0
5	27.2	480.7	495.84	496.51	0.7	136027	152968	16941	2.76	2.82	0.1
4	28.5	474.1	489.22	489.93	0.7	127266	145681	18414	2.79	2.87	0.1
3	31.3	459.3	477.11	477.9	0.8	105616	121356	15739	2.03	2.09	0.1
2	32.4	456.9	474.94	475.68	0.7	103748	119274	15527	1.91	1.99	0.1
1[5]	32.6	456.3	474.44	475.18	0.7	103767	119304	15537	2.49	2.56	0.1

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 3.4

Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Deep Breach - Local 1/2 PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL (ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1174.2	17.7	250	53319	53069	2.8	12.3	9.5
27	0.6	1104.8	1106.8	1126.0	19.2	250	51361	51111	2.5	10.8	8.3
26	1.5	1049.8	1052.2	1070.1	17.9	250	48907	48657	2.1	9.5	7.4
25[2]	2.2	1023.1	1025.0	1043.5	18.5	250	24961	24711	2.6	1.7	-0.9
24	3.2	958.6	961.1	985.3	24.3	250	132201	131951	2.0	10.2	8.2
23	4.1	926.1	928.6	948.1	19.5	250	126557	126307	2.1	7.9	5.9
22	5.0	895.7	897.6	914.8	17.2	250	122257	122007	2.7	11.9	9.2
21	5.6	848.3	853.8	872.7	18.9	250	78149	77899	0.7	1.8	1.1
20	6.9	846.1	849.7	867.6	18.0	250	54950	54700	1.4	4.1	2.7
19	7.8	836.1	838.7	855.7	17.0	250	49982	49732	1.9	7.0	5.0
18	9.7	785.2	787.5	802.8	15.4	250	47623	47373	2.2	8.1	5.8
17	10.6	745.0	748.0	764.7	16.7	250	46849	46599	1.7	6.6	4.9
16	10.9	739.4	742.0	756.3	14.3	250	46562	46312	1.9	6.8	4.9
15[3]	11.5	725.0	728.9	740.2	11.3	250	35855	35605	1.3	1.9	0.6
14	12.9	714.0	717.2	730.5	13.3	250	30690	30440	1.6	5.2	3.7
13	14.4	693.3	696.2	703.0	6.8	250	30047	29797	1.7	3.4	1.7
12	15.3	674.9	677.7	685.2	7.5	250	29496	29246	1.8	3.9	2.1
11	17.2	634.8	637.0	643.3	6.3	250	28025	27775	1.7	3.2	1.5
10	19.1	595.0	597.8	605.9	8.1	250	25857	25607	1.8	4.1	2.4
9	22.0	534.9	538.0	545.1	7.1	250	23208	22958	1.6	3.6	2.0
8	24.0	503.9	507.7	513.1	5.5	250	20388	20138	1.3	2.4	1.1
7	25.1	494.1	498.3	502.5	4.1	250	18028	17778	1.2	2.0	0.8
6[4]	26.6	485.7	487.2	492.0	4.7	250	15362	15112	0.9	2.0	1.1
5	27.2	480.7	483.0	487.8	4.8	250	14264	14014	0.8	1.7	0.9
4	28.5	474.1	476.6	481.3	4.6	250	12535	12285	1.0	1.7	0.7
3	31.3	459.3	462.8	468.0	5.2	250	9649	9399	0.7	1.4	0.7
2	32.4	456.9	460.8	466.3	5.5	250	8409	8159	0.6	0.8	0.3
1[5]	32.6	456.3	460.3	465.9	5.6	250	8407	8157	0.9	1.6	0.7

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Table 3.5

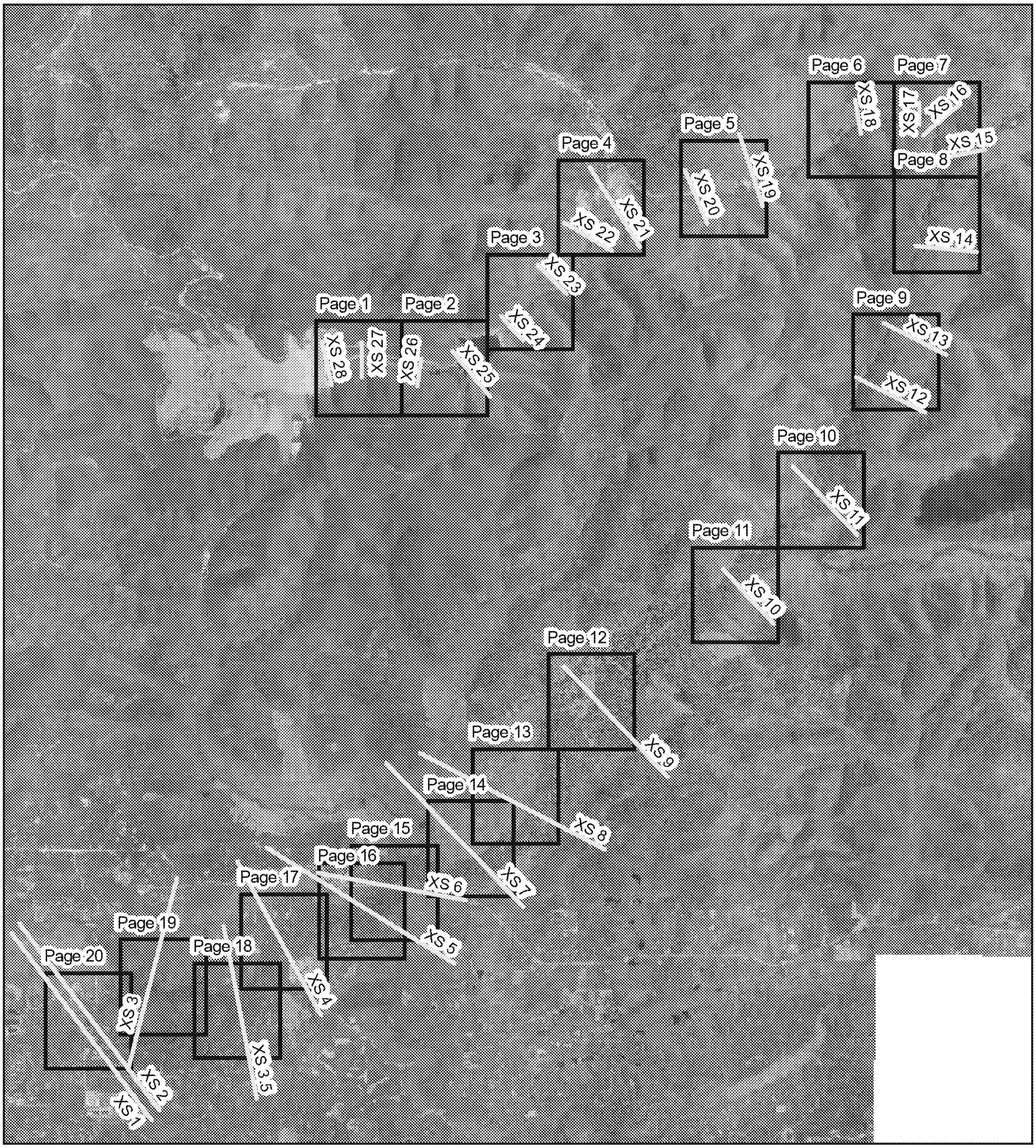
Fairbanks Gold Mining, Inc.
Fort Knox Project
TSF and WSR Dam Break Inundation Analysis

HEC-RAS Results - Deep Breach - Local PMP

Cross Section	Distance from TSF (mi)	Min Channel Elevation (ft)	Maximum WSEL(ft)			Flow (cfs)			Velocity (fps)		
			No Dam Break	Dam Break	Δ WSEL	No Dam Break	Dam Break	Δ Flow	No Dam Break	Dam Break	Δ Velocity
28[1]	0.0	1154.8	1156.6	1176.1	19.5	250	67365	67115	2.8	13.1	10.3
27	0.6	1104.8	1106.8	1128.0	21.2	250	64889	64639	2.5	11.5	9.0
26	1.5	1049.8	1052.2	1071.9	19.7	250	61932	61682	2.1	10.2	8.1
25[2]	2.2	1023.1	1025.0	1043.9	18.9	250	30371	30121	2.6	2.0	-0.6
24	3.2	958.6	961.1	985.8	24.7	250	138047	137797	2.0	10.3	8.3
23	4.1	926.1	928.6	948.5	19.9	250	132557	132307	2.1	8.0	6.0
22	5.0	895.7	897.6	915.1	17.6	250	128454	128204	2.7	12.1	9.4
21	5.6	848.3	853.8	873.7	19.8	250	83611	83361	0.7	1.8	1.1
20	6.9	846.1	849.7	868.6	18.9	250	62009	61759	1.4	4.2	2.8
19	7.8	836.1	838.7	856.6	17.9	250	56797	56547	1.9	7.2	5.2
18	9.7	785.2	787.5	803.6	16.1	250	54185	53935	2.2	8.3	6.1
17	10.6	745.0	748.0	765.7	17.7	250	53313	53063	1.7	6.9	5.2
16	10.9	739.4	742.0	757.1	15.1	250	52999	52749	1.9	7.0	5.1
15[3]	11.5	725.0	728.9	741.0	12.1	250	40346	40096	1.3	1.9	0.7
14	12.9	714.0	717.2	731.3	14.1	250	34973	34723	1.6	5.4	3.9
13	14.4	693.3	696.2	703.3	7.1	250	34200	33950	1.7	3.5	1.8
12	15.3	674.9	677.7	685.6	7.8	250	33589	33339	1.8	3.9	2.2
11	17.2	634.8	637.0	643.7	6.6	250	31913	31663	1.7	3.2	1.5
10	19.1	595.0	597.8	606.4	8.6	250	29474	29224	1.8	4.2	2.5
9	22.0	534.9	538.0	545.5	7.5	250	26398	26148	1.6	3.6	2.0
8	24.0	503.9	507.7	513.5	5.8	250	23091	22841	1.3	2.4	1.1
7	25.1	494.1	498.3	502.7	4.4	250	20637	20387	1.2	2.0	0.8
6[4]	26.6	485.7	487.2	492.3	5.0	250	17520	17270	0.9	2.1	1.2
5	27.2	480.7	483.0	488.1	5.1	250	16241	15991	0.8	1.7	0.9
4	28.5	474.1	476.6	481.6	4.9	250	14216	13966	1.0	1.7	0.8
3	31.3	459.3	462.8	468.3	5.4	250	10695	10445	0.7	1.4	0.7
2	32.4	456.9	460.8	466.6	5.8	250	9548	9298	0.6	0.9	0.3
1[5]	32.6	456.3	460.3	466.2	5.9	250	9545	9295	0.9	1.7	0.8

[1] TSF downstream toe
[2] Water Storage Reservior
[3] Confluence of Fish Creek and Little Chena River
[4] Chena Hot Springs Road
[5] Confluence of Little Chena River and Chena River

Appendix 4
Inundation Limits for TSF Shallow Breach Scenarios



EXPLANATION

Cross Section | Mapbook Page

Feet
0 12,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 12,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_Index.mxd				

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
SRK JOB NO. **73400.040**
REVISION **A**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook01_Cross_Sections_1000.mxd		

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Page:1

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20

Page:2

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

Page:3

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

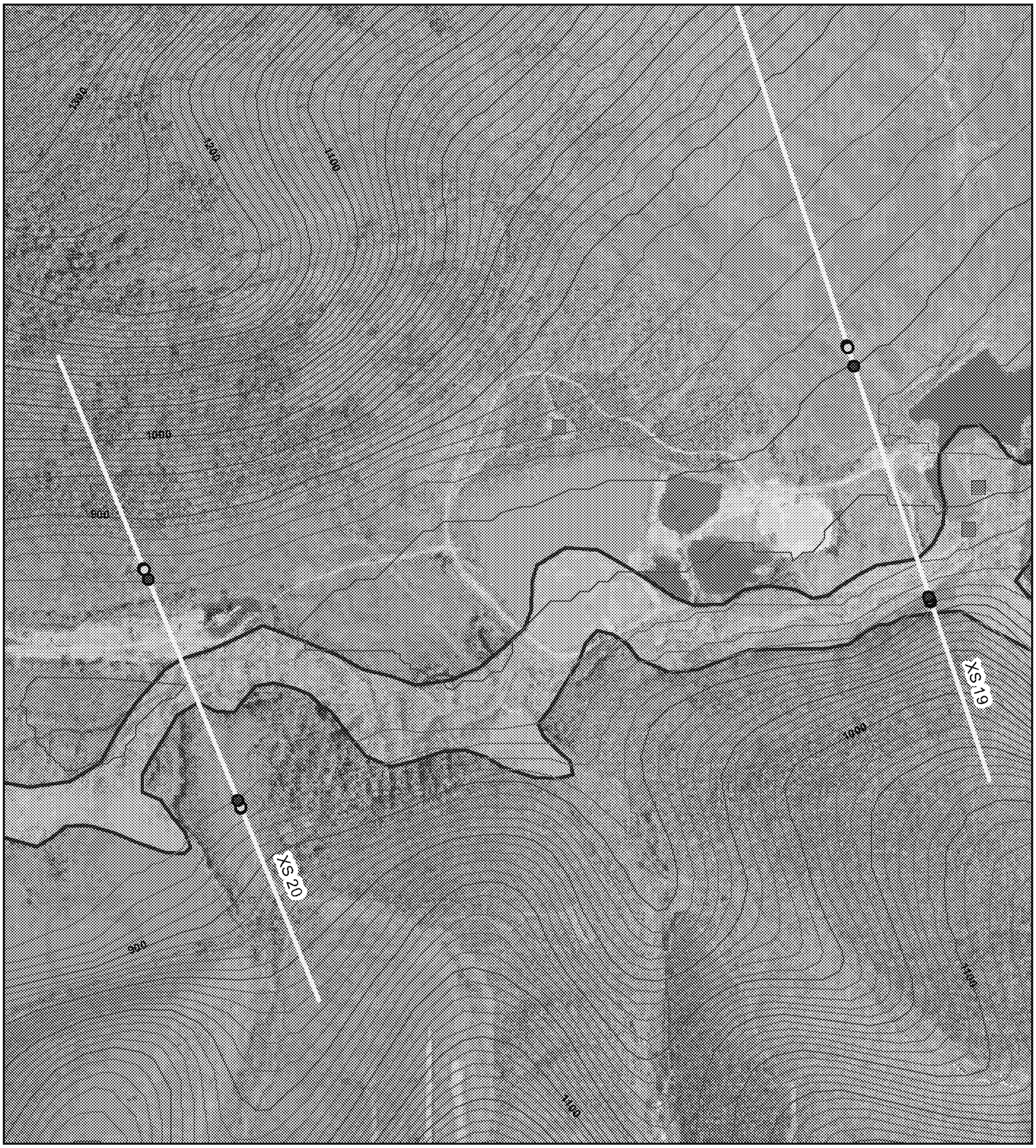
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20
Page:4

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
SRK JOB NO. **73400.040**
REVISION **A**



Cross Section	Clear Day	Fema 100 Year Flood Zone
Structure	Local 1/2 PMP	Fema 500 Year Flood Zone
Road	Local PMP	

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook01_Cross_Sections_1000.mxd		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Page:5

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION A
SRK JOB NO.	73400.040	

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 7 8 9 10 11 12 13 14 16 17 18 19 20
Page:6

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Clear Day
Fema 100 Year Flood Zone
Structure
Local 1/2 PMP
Fema 500 Year Flood Zone
Road
Local PMP

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

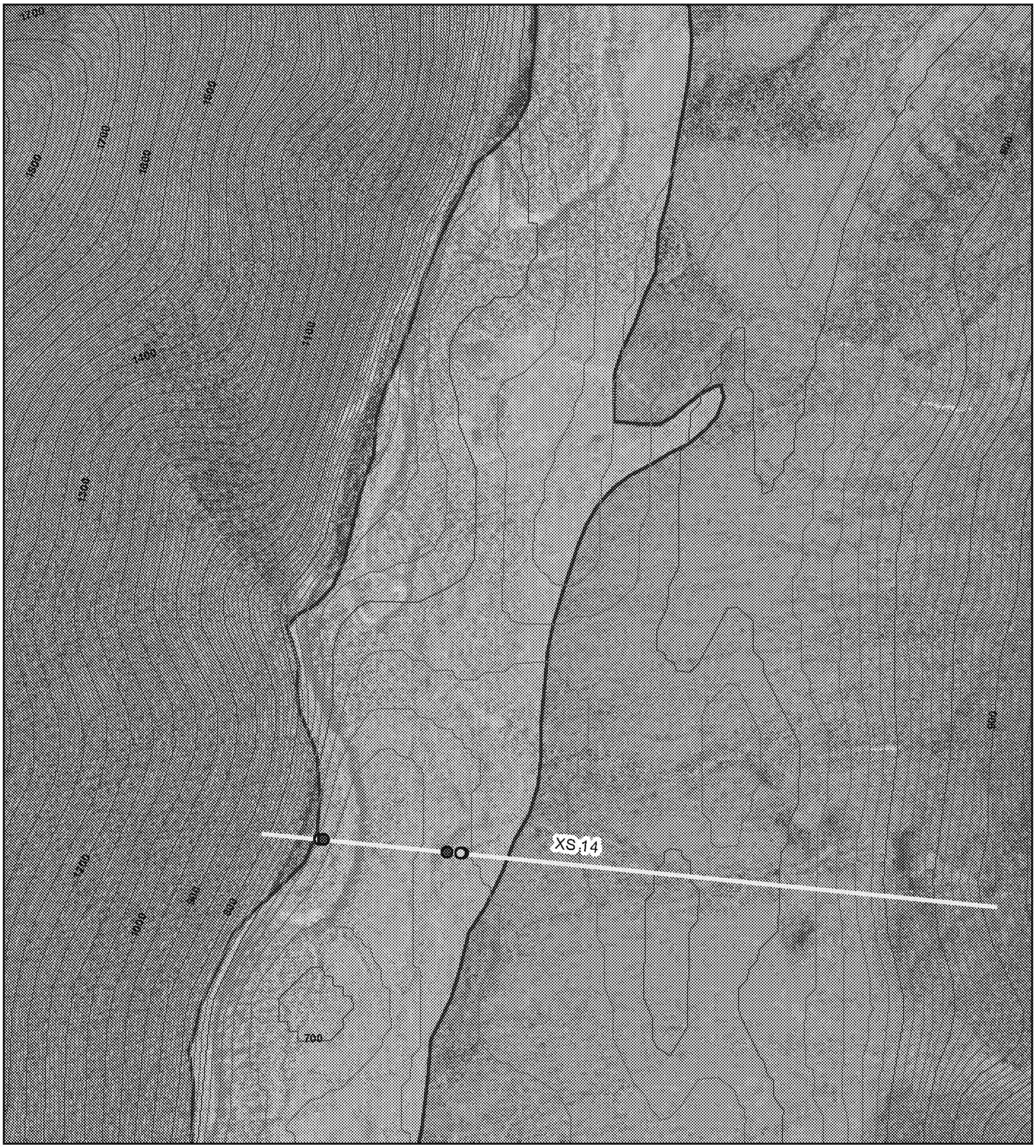
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page:7

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. MAPBOOK 1
SRK JOB NO. 73400.040
REVISION A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

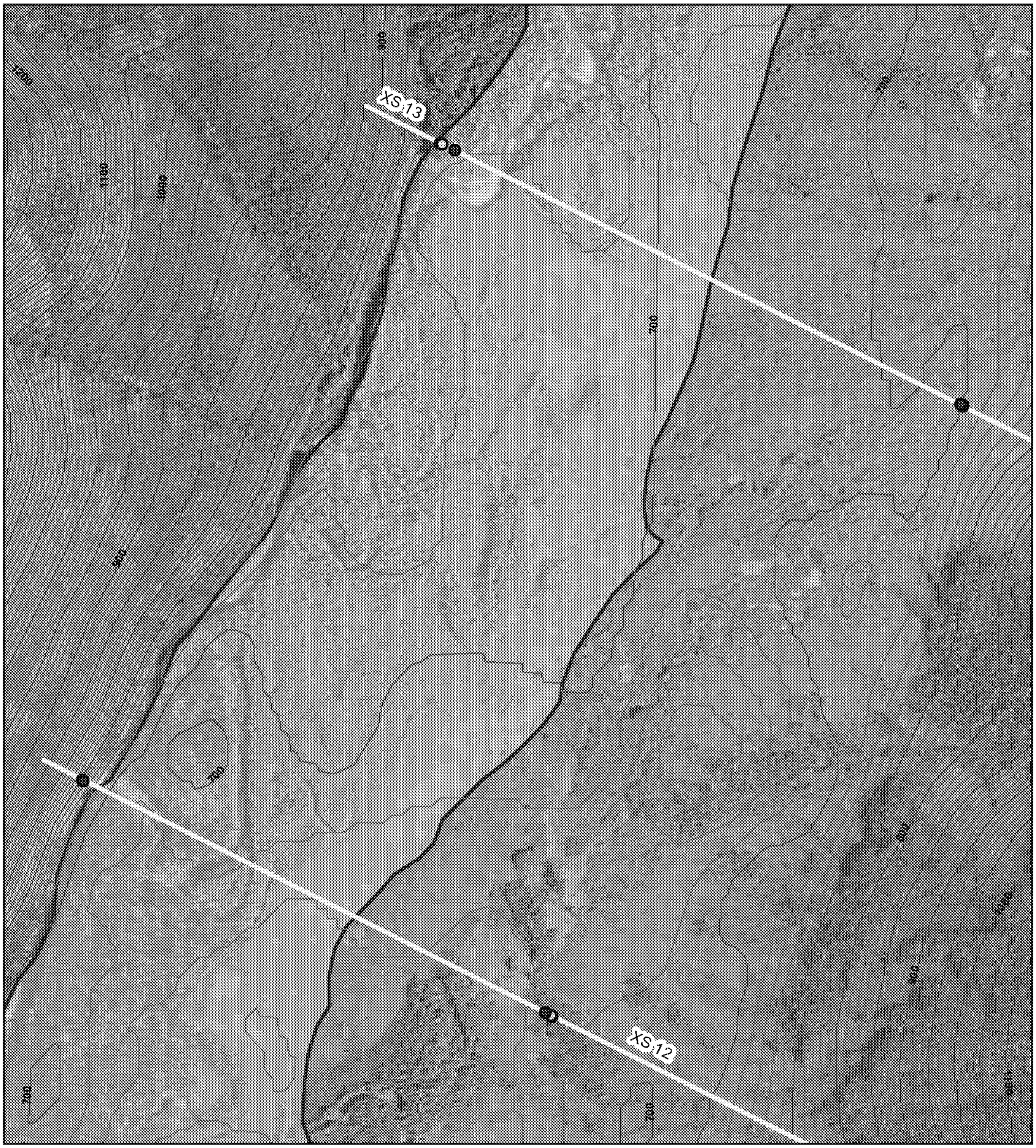
DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook01_Cross_Sections_1000.mxd		

Page:8

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. MAPBOOK 1
SRK JOB NO. 73400.040
REVISION A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 10 11 12 13 14 16 17 18 19 20

Page:9

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section	Clear Day	Fema 100 Year Flood Zone
Structure	Local 1/2 PMP	Fema 500 Year Flood Zone
Road	Local PMP	

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 11 12 13 14 16 17 18 19 20
Page: 10

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 12 13 14 16 17 18 19 20
Page: 11

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

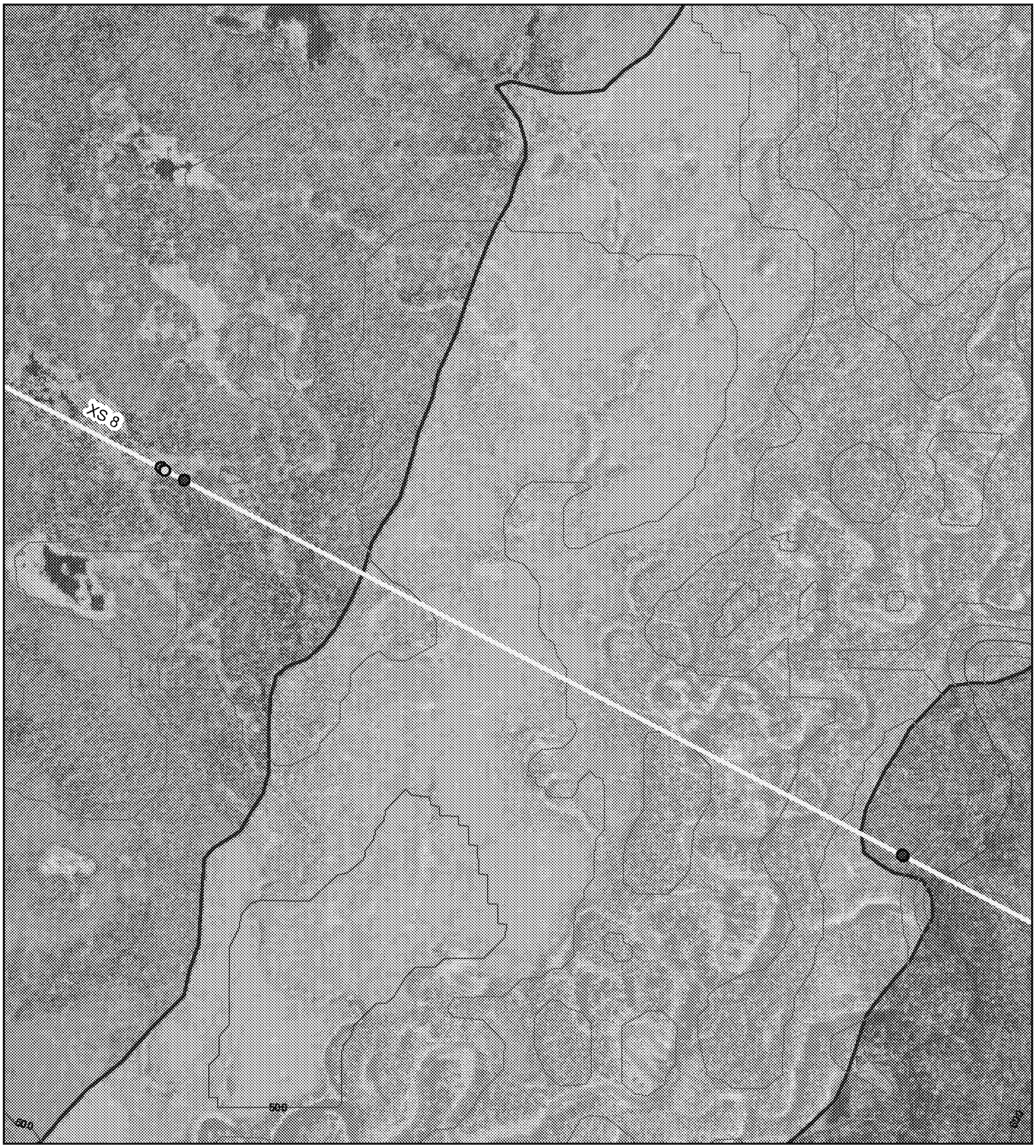
1 2 3 4 5 6 7 8 9 10 11 13 14 16 17 18 19 20

Page: 12

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
SRK JOB NO. **73400.040**
REVISION **A**



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 14 16 17 18 19 20

Page: 13

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook01_Cross_Sections_1000.mxd		

Page: 14

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. MAPBOOK 1
SRK JOB NO. 73400.040
REVISION A

Cross Section	Clear Day	Fema 100 Year Flood Zone
Structure	Local 1/2 PMP	Fema 500 Year Flood Zone
Road	Local PMP	

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

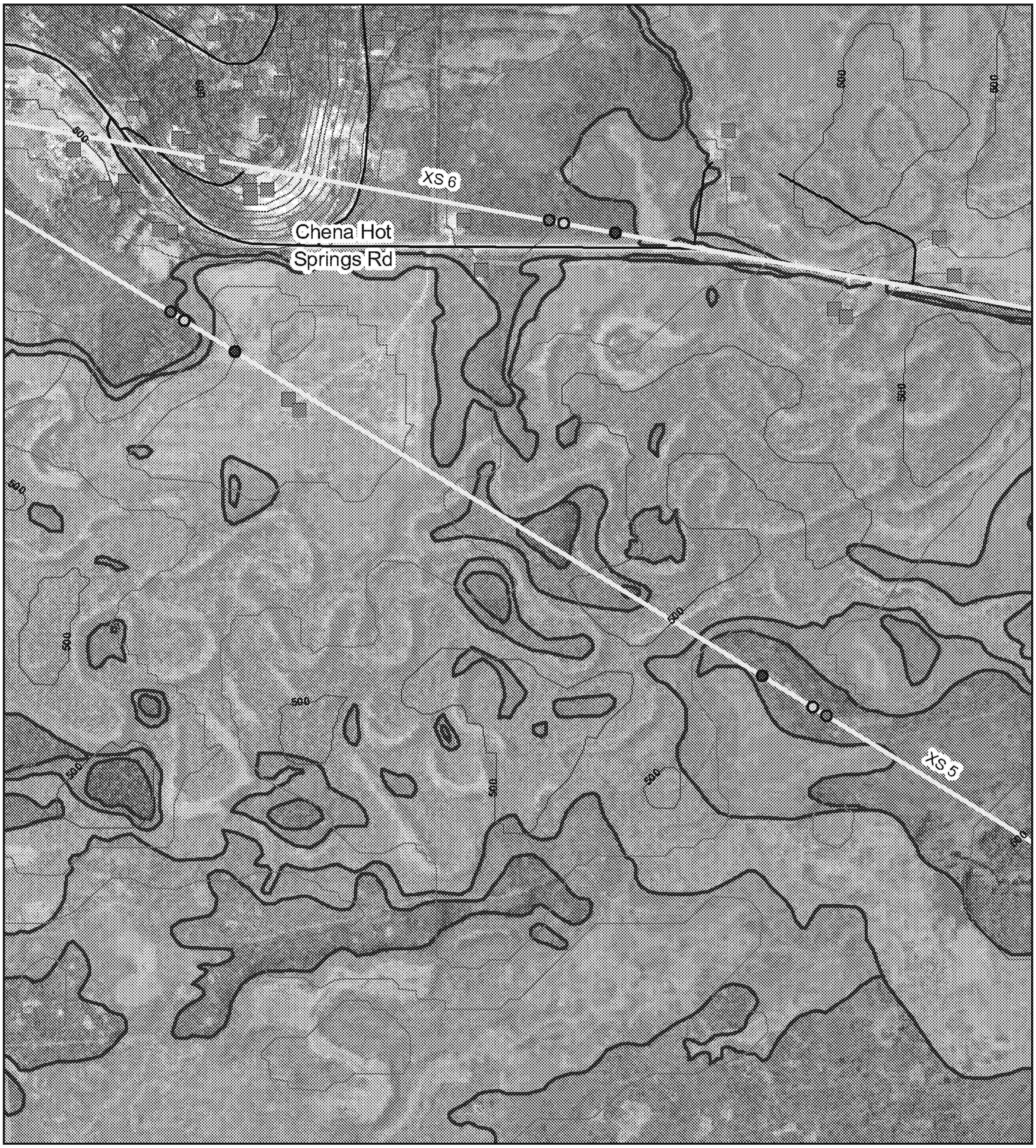
DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook01_Cross_Sections_1000.mxd		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 17 18 19 20
Page: 15

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
SRK JOB NO. **73400.040**
REVISION **A**



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

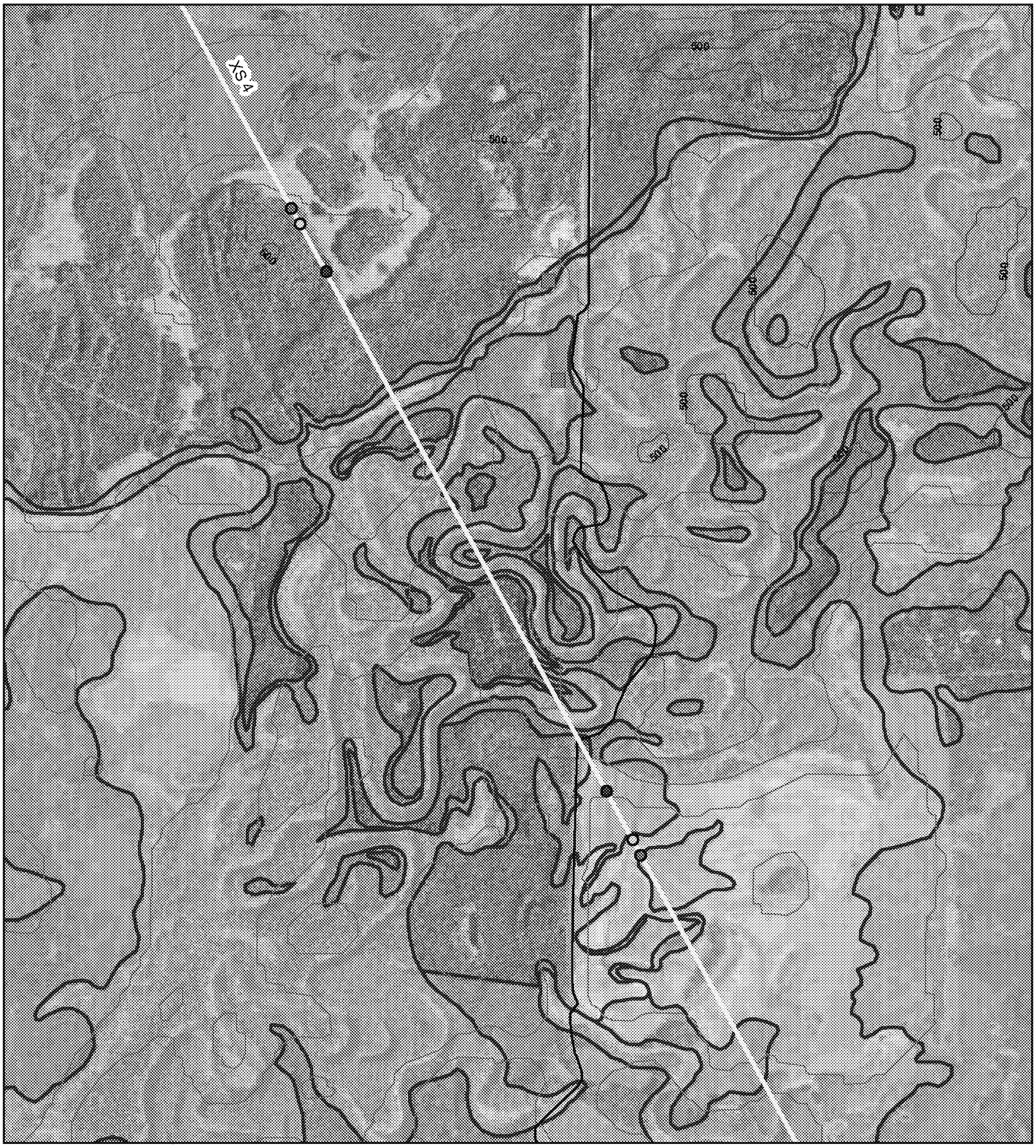
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 17 18 19 20
Page: 16

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

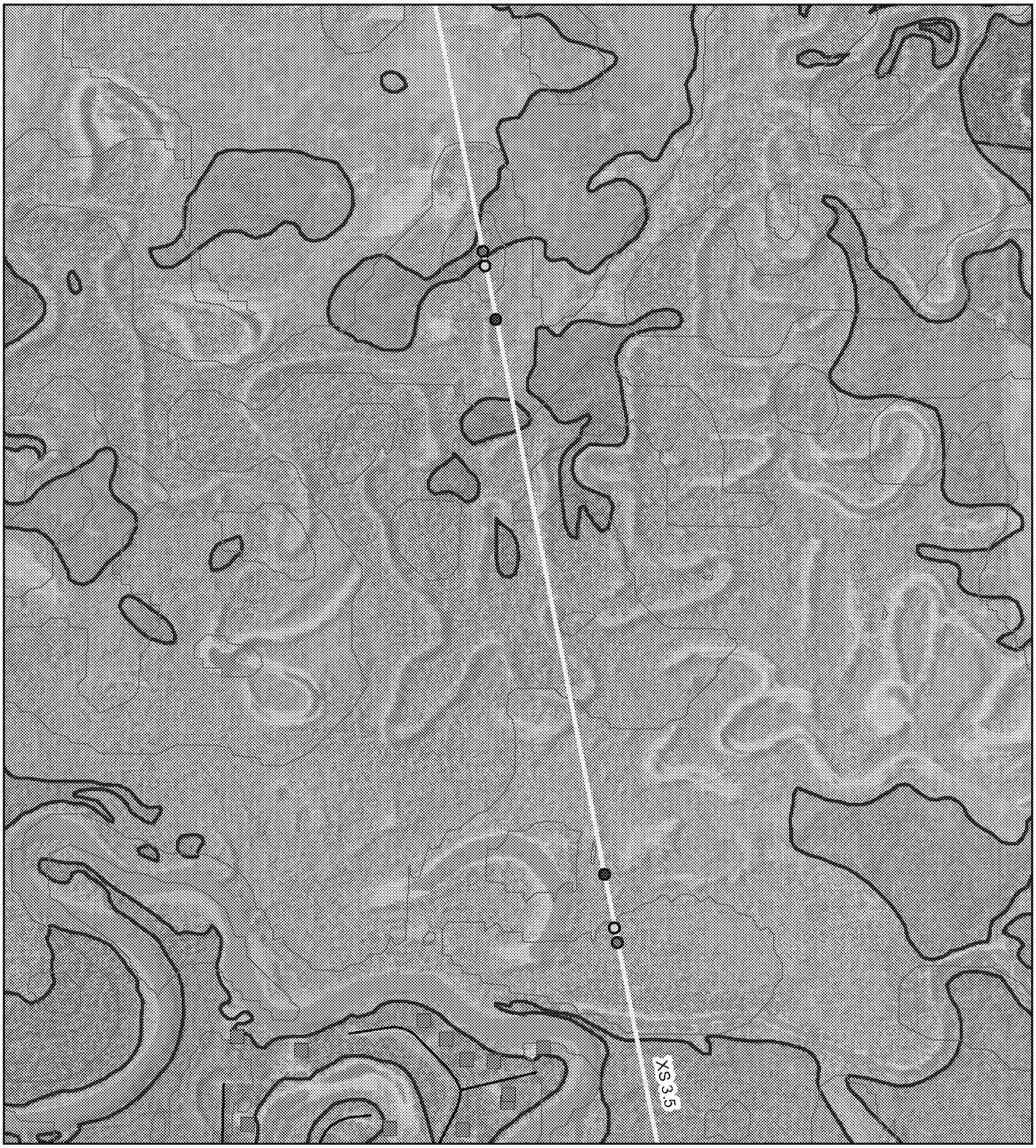
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page: 17

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A



Cross Section | Clear Day | Fema 100 Year Flood Zone
Structure | Local 1/2 PMP | Fema 500 Year Flood Zone
Road | Local PMP

Feet

0 1,000

N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

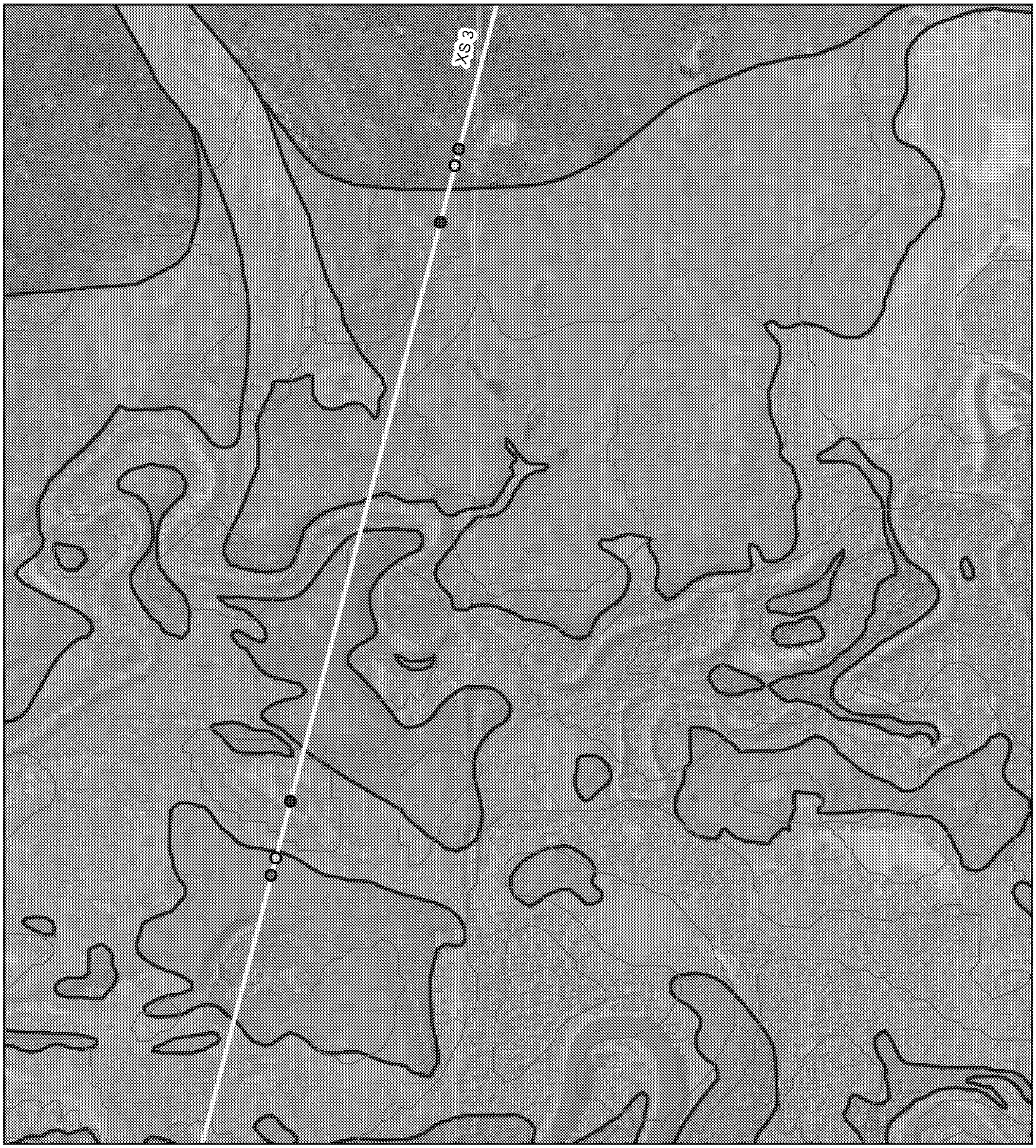
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page: 18

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO.	MAPBOOK 1	REVISION
SRK JOB NO.	73400.040	A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 20

Page: 19

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. MAPBOOK 1
REVISION A
SRK JOB NO. 73400.040

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook01_Cross_Sections_1000.mxd				

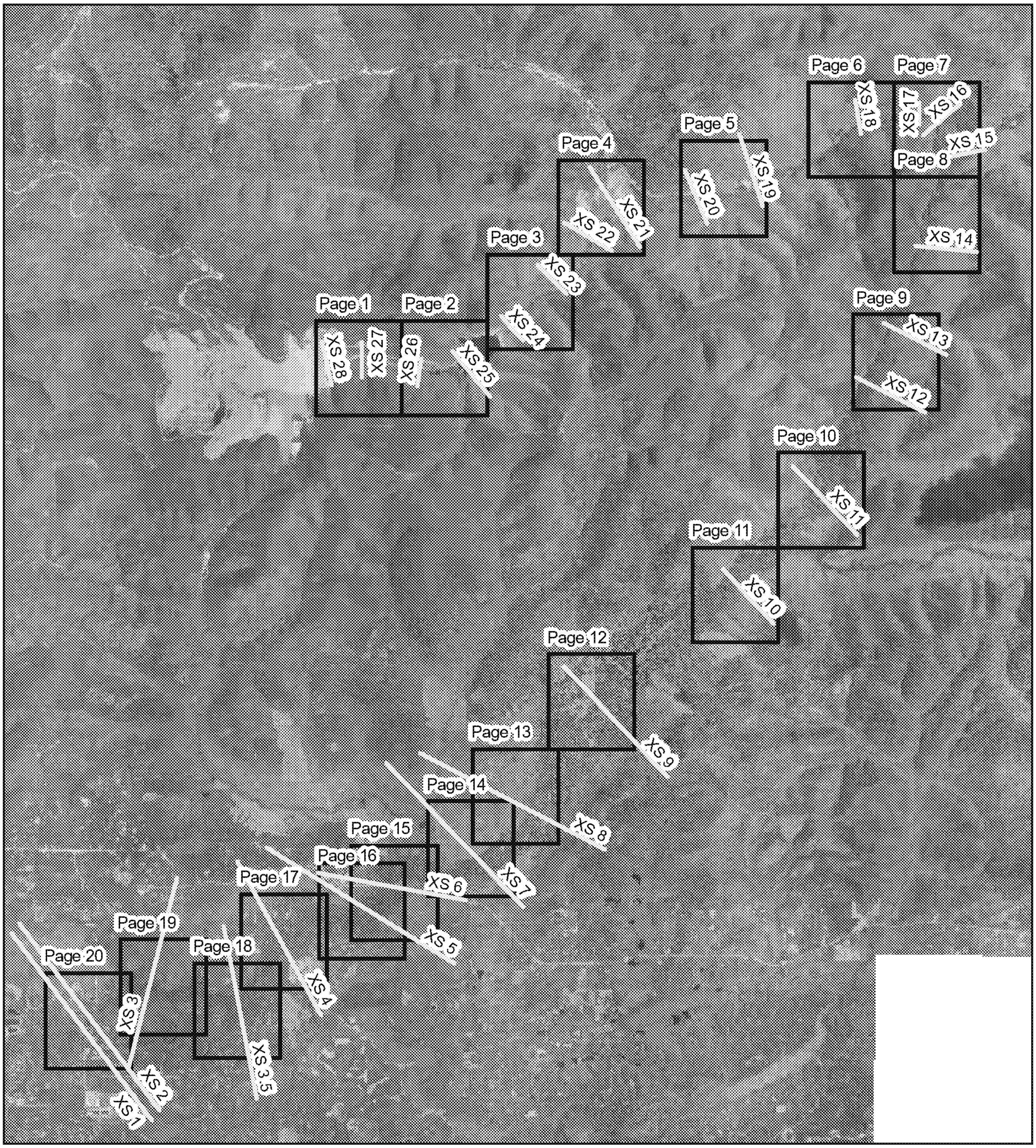
Page:20

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF SHALLOW BREACH SCENARIOS

DRAWING NO. **MAPBOOK 1**
SRK JOB NO. **73400.040**
REVISION **A**

Appendix 5
Inundation Limits for TSF Deep Breach Scenarios



EXPLANATION

Cross Section   Mapbook Page

Feet

0   12,000

N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 12,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_Index.mxd		

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2	REVISION
SRK JOB NO.	73400.040	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page:1

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2	REVISION
SRK JOB NO.	73400.040	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000

N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page:2

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2
SRK JOB NO.	73400.040
REVISION	A

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_1000.mxd		

1 2 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20
Page:3

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20

Page:4

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. MAPBOOK 2
REVISION A
SRK JOB NO. 73400.040

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20
Page:5

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_1000.mxd		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Page:6

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
SRK JOB NO. **73400.040**
REVISION **A**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

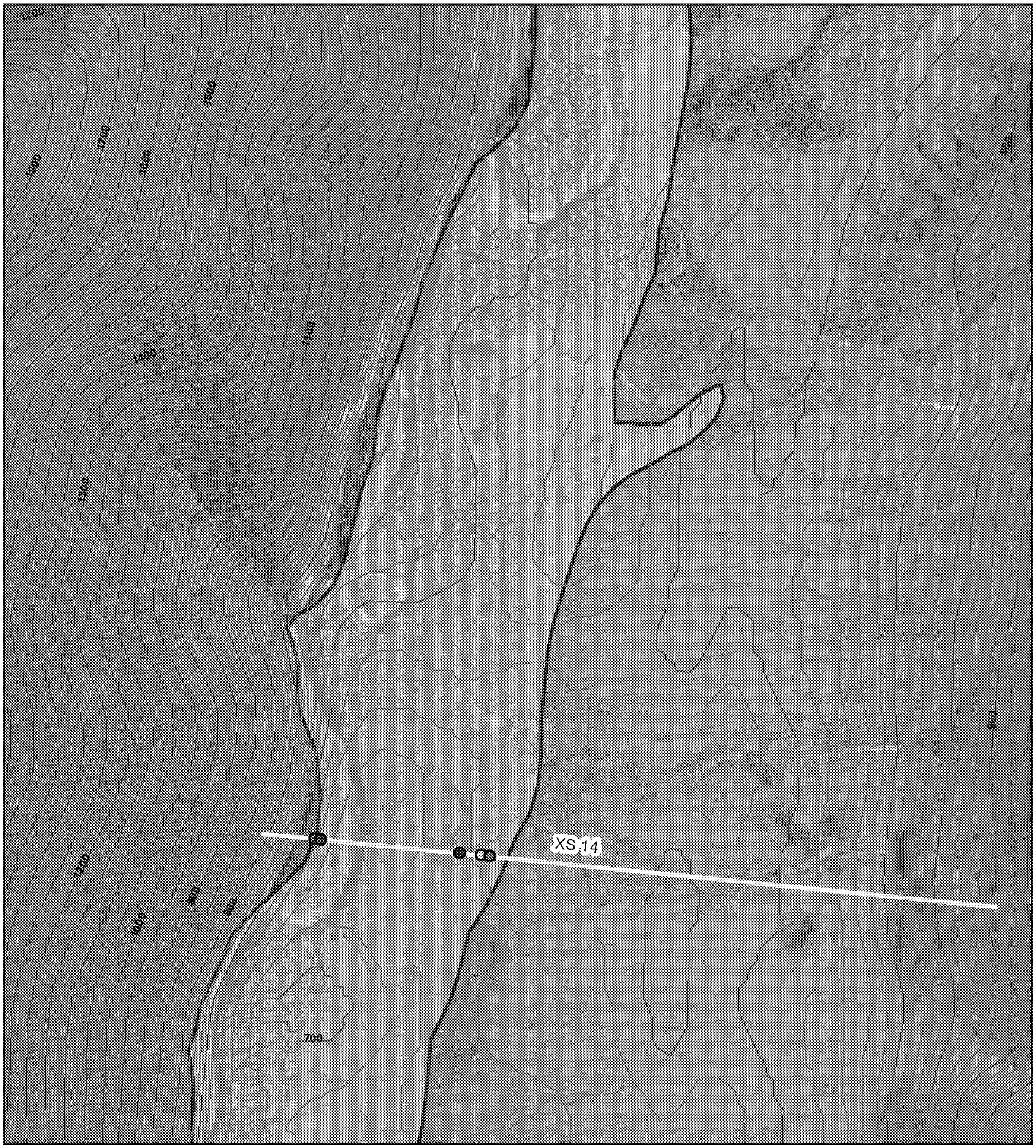
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

Page:7

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. MAPBOOK 2
REVISION A
SRK JOB NO. 73400.040



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

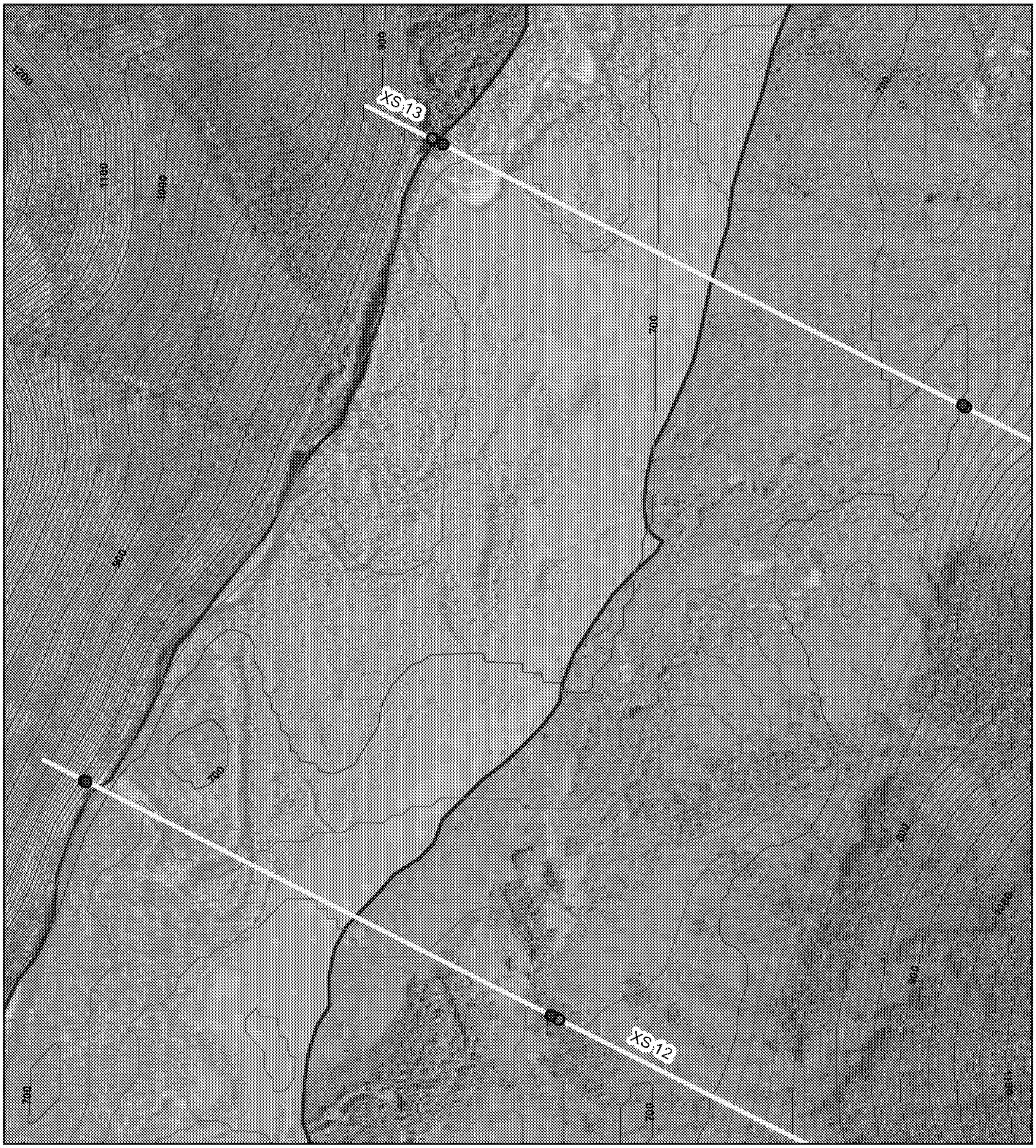
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 9 10 11 12 13 14 16 17 18 19 20
Page:8

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 10 11 12 13 14 16 17 18 19 20

Page:9

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_1000.mxd		

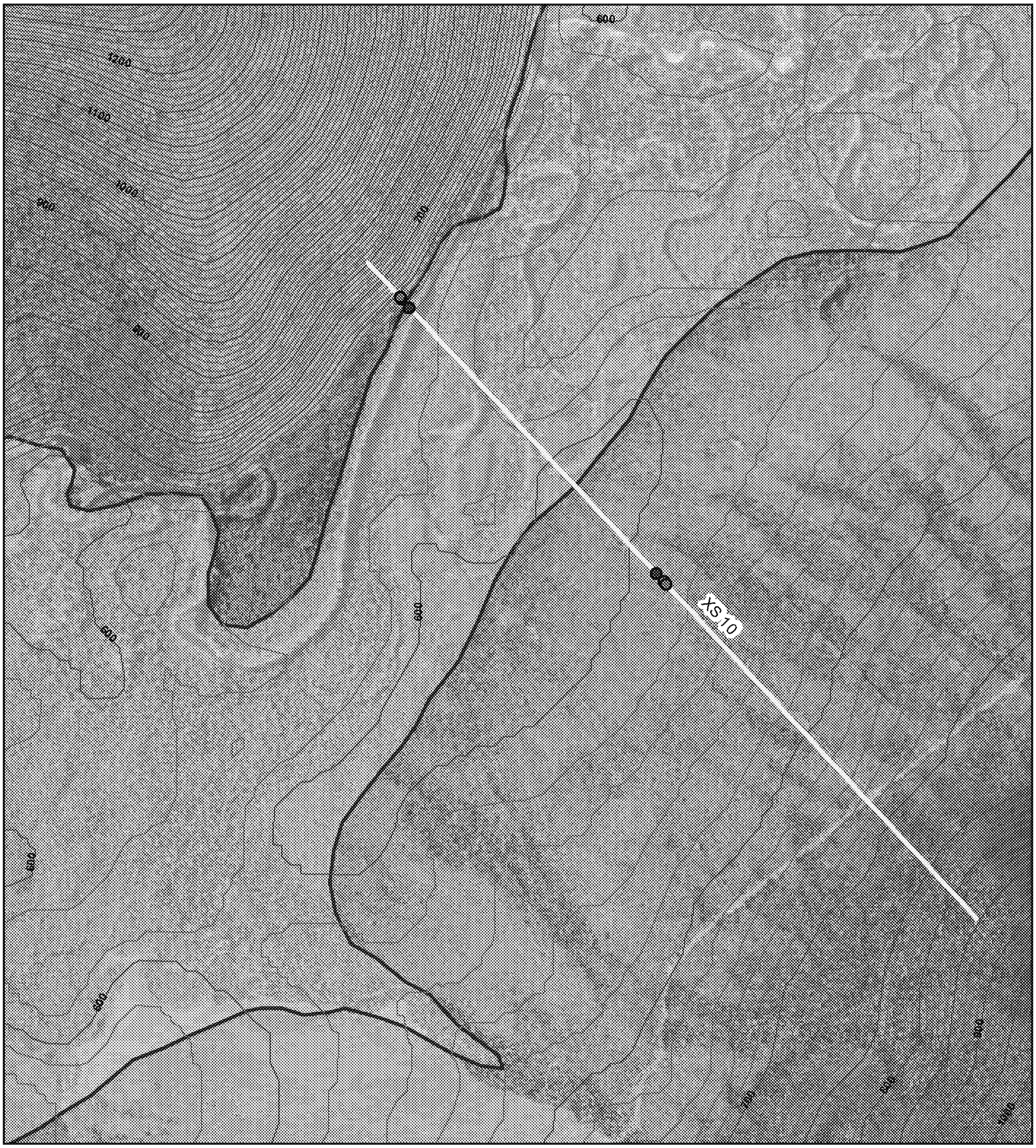
1 2 3 4 5 6 7 8 9 11 12 13 14 16 17 18 19 20

Page: 10

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2	REVISION
SRK JOB NO.	73400.040	A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page: 11

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

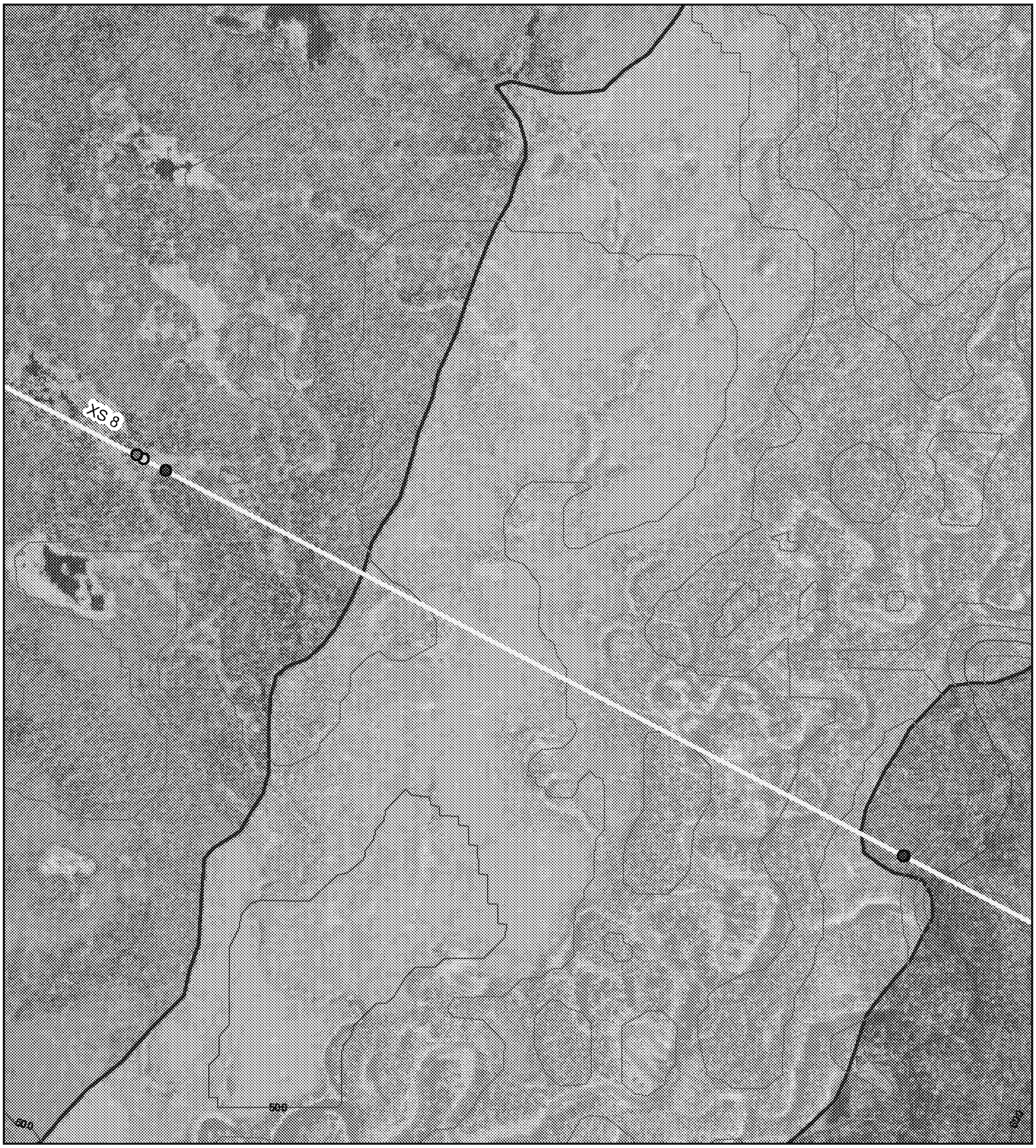
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

Page: 12

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2	REVISION
SRK JOB NO.	73400.040	A



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20

Page: 13

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
SRK JOB NO. **73400.040**
REVISION **A**

Cross Section
Clear Day
Fema 100 Year Flood Zone
Structure
Local 1/2 PMP
Fema 500 Year Flood Zone
Road
Local PMP

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_1000.mxd		

1 2 3 4 5 6 7 8 9 10 11 12 13 16 17 18 19 20
Page: 14

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

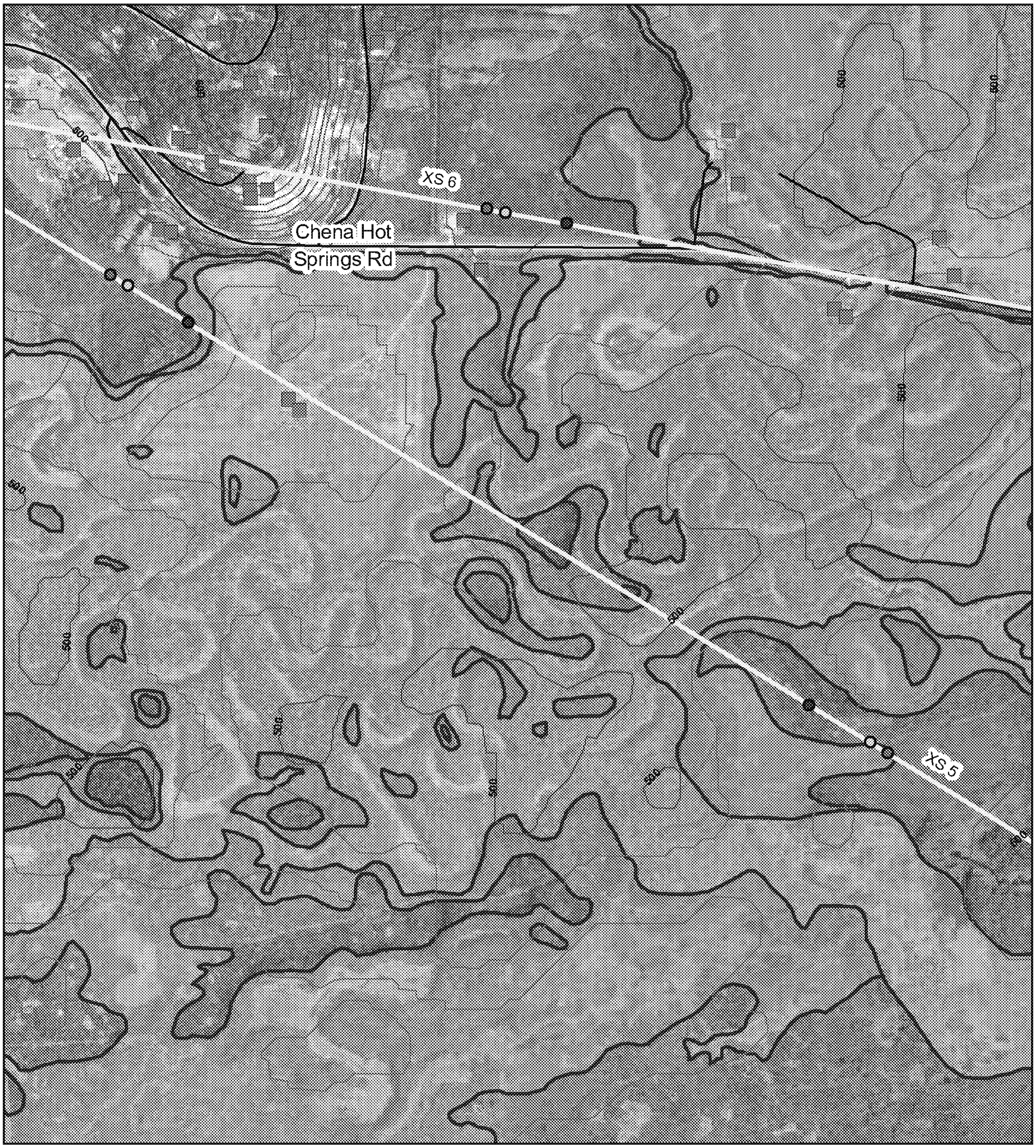
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 17 18 19 20
Page: 15

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
SRK JOB NO. **73400.040**
REVISION **A**



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 17 18 19 20

Page: 16

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

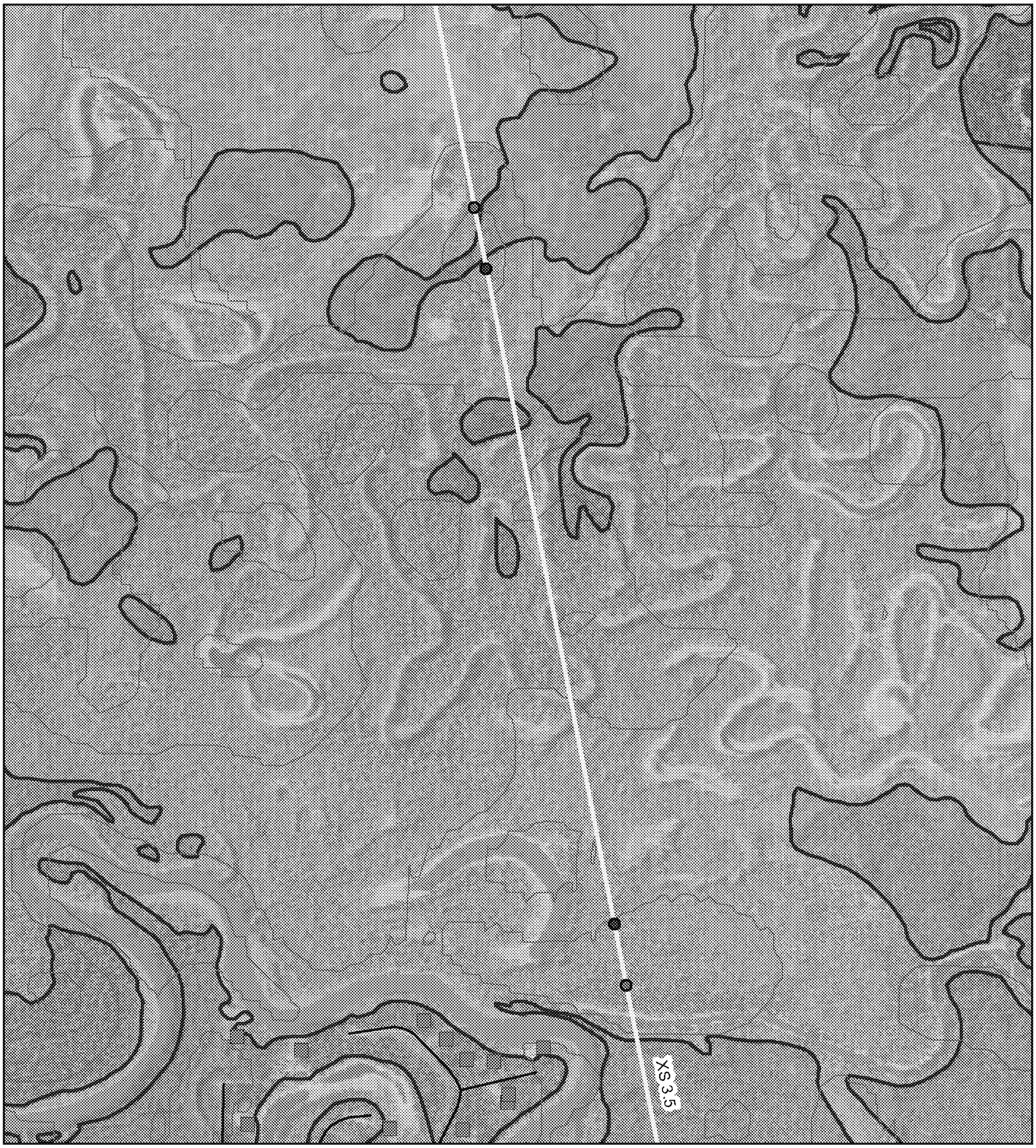
DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

Page: 17

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
SRK JOB NO. **73400.040**
REVISION **A**



Cross Section	Clear Day	Fema 100 Year Flood Zone
Structure	Local 1/2 PMP	Fema 500 Year Flood Zone
Road	Local PMP	

Feet

0 1,000

N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN: SN	DRAWN: BVB	REVIEWED: DH
SCALE: 1 inch = 1,000 feet		DATE: 02/25/2010
FILE NAME: Mapbook02_Cross_Sections_1000.mxd		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Page: 18

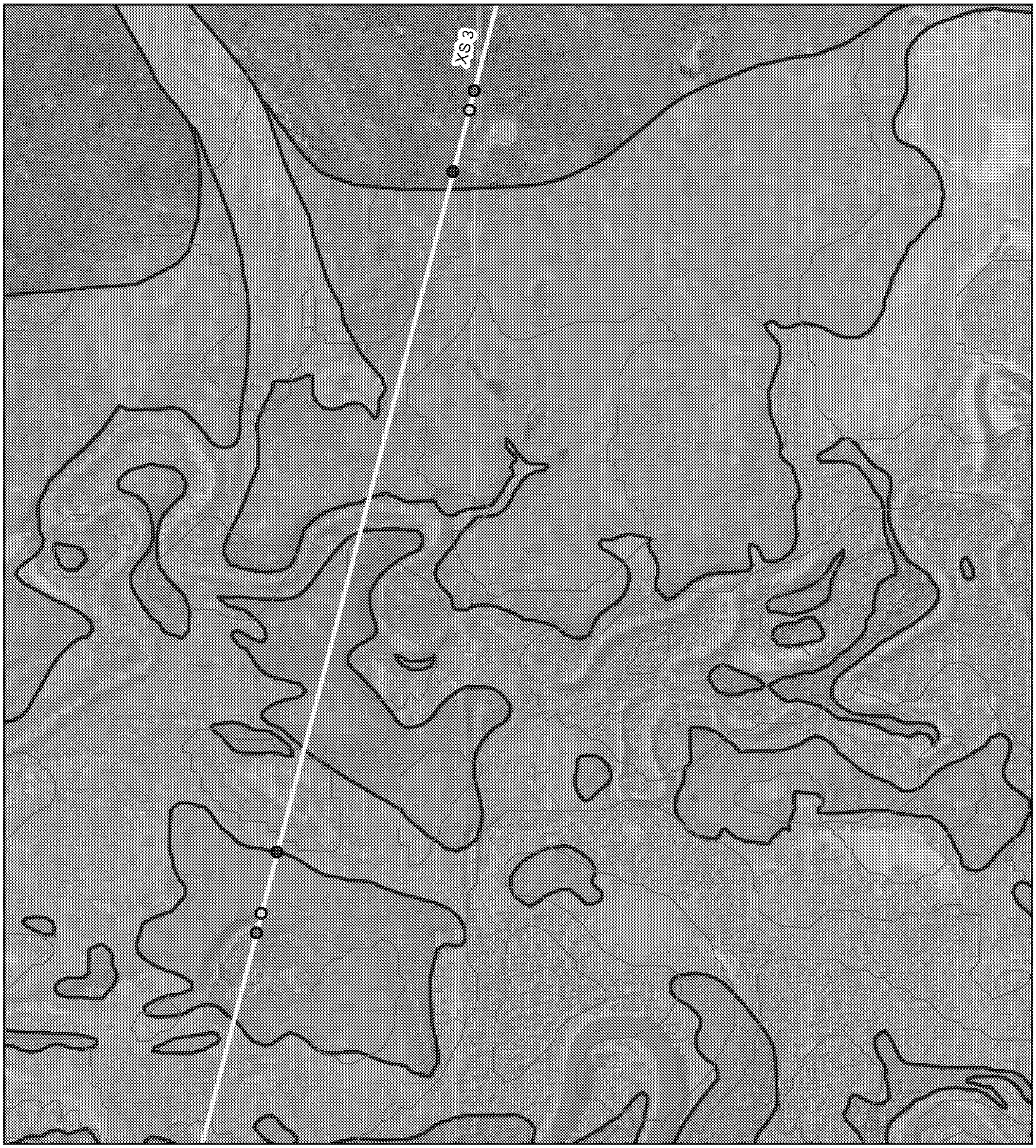
FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**

REVISION **A**

SRK JOB NO. **73400.040**



Cross Section
Structure
Road
Clear Day
Local 1/2 PMP
Local PMP
Fema 100 Year Flood Zone
Fema 500 Year Flood Zone

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 20

Page: 19

FAIRBANKS GOLD MINING, INC.
FORT KNOX MINE

DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO. **MAPBOOK 2**
REVISION **A**
SRK JOB NO. **73400.040**

Cross Section
Clear Day
Fema 100 Year Flood Zone
Structure
Local 1/2 PMP
Fema 500 Year Flood Zone
Road
Local PMP

Feet
0 1,000
N

SRK Consulting
Engineers and Scientists

NAD 83 State Plane Alaska Zone 3 Feet

DESIGN:	SN	DRAWN:	BVB	REVIEWED:	DH
SCALE:	1 inch = 1,000 feet			DATE:	02/25/2010
FILE NAME:	Mapbook02_Cross_Sections_1000.mxd				

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Page:20

FAIRBANKS GOLD MINING, INC. FORT KNOX MINE

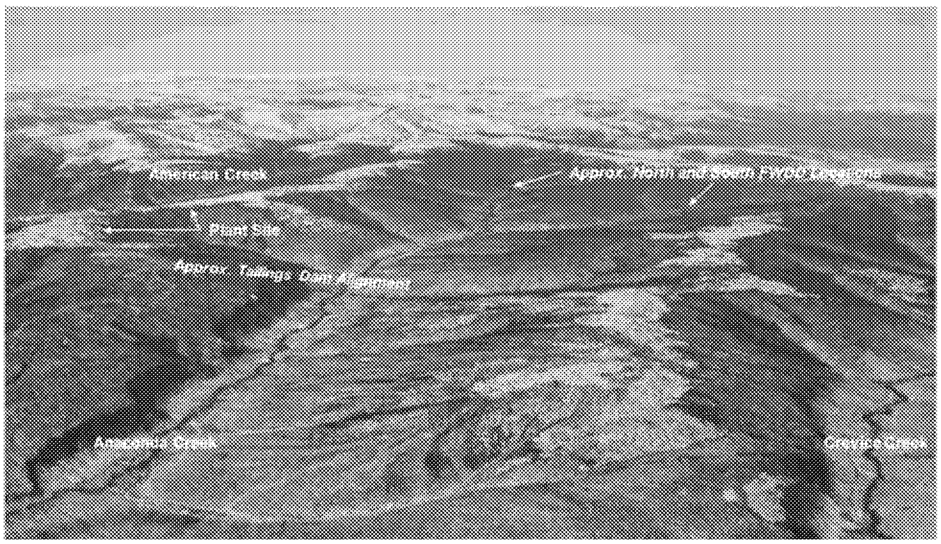
DRAWING TITLE:
TSF DEEP BREACH SCENARIOS

DRAWING NO.	MAPBOOK 2	REVISION
SRK JOB NO.	73400.040	A

Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop

Prepared for

Donlin Gold



Prepared by

SRK Consulting (Canada) Inc.
181202.010
March 2015

Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop

March 2015

Prepared for

Donlin Gold
4720 Business Park Blvd., Suite G-25
Anchorage, AK 99503
USA

Tel: +1 907 273 0200
Web: www.donlingold.com

Prepared by

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2
Canada

Tel: +1 604 681 4196
Web: www.srk.com

Project No: 181202.010

File Name: DonlinGold_FMEAWorkshop_Report_181202.010_20150306FNL_DEH.docx

Table of Contents

List of Tables

Appendices

1 Introduction

Donlin Gold LLC (Donlin Gold) is proposing to construct a tailings storage facility (TSF) and fresh water reservoir (Snow Gulch) as part of the development of the Donlin Gold Project. The project is currently undergoing environmental review and permitting. Potential environmental impacts and project alternatives are being evaluated in an Environmental Impact Statement under development by the US Army Corps of Engineers (USACE). The draft EIS is to be available for public review in fall 2015. Concurrently, Donlin Gold is developing applications for project permits and approvals.

Donlin Gold submitted initial application materials for the TSF Dam, the Snow Gulch Reservoir Dam, and five other project-related dams to the Alaska Department of Natural Resources (ADNR) Dam Safety Program. ADNR Dam Safety and Construction Unit commented on the initial application materials and noted that a technical risk assessment in the form of a Failure Modes and Effects Analysis (FMEA) will ultimately be required for dams having a Class 1 hazard potential (as defined in state regulations), which may include both the TSF Dam and the Snow Gulch Reservoir Dam.

Donlin Gold subsequently commissioned SRK Consulting to facilitate an early stage FMEA for these two dams. The early stage FMEA will inform subsequent stages of site investigation and design. It may also provide inputs to the EIS and dam permitting processes, but a later stage FMEA may be required to fully meet the expectations of the ADNR Dam Safety Program.

This report summarizes the early stage FMEA workshop objectives, participants, methodology, and outcomes.

2 Workshop Objectives

The overall objective of the early stage FMEA workshop was to identify and evaluate risks associated with the TSF and the Snow Gulch Reservoir, with a view to ensuring that these risks are addressed in the current and future stages of investigation and design.

3 Workshop Participants and Methodology

SRK hosted and facilitated the early stage FMEA workshop at its offices in Vancouver, BC, on December 2 and 3, 2014.

The two-day workshop included participation by representatives from Donlin Gold, the Alaska Dam Safety Unit, AECOM (formerly URS, consultants for the USACE), the landowners (the Kuskokwim Corporation and Calista Corporation), and engineers involved in the design of the TSF and Snow Gulch Reservoir dams (BGC Engineering). The participants are listed in Table 1.

The workshop was facilitated by Daryl Hockley, PE, a civil engineer with over 25 years of experience, including facilitation of FMEAs for tailings facilities at other mines in Alaska, northern Canada and overseas.

Table 1: FMEA Workshop Participants

Name	Affiliation	E-mail
Nick Enos	Donlin Gold	renos@donlingold.com
James Fueg	Donlin Gold	jfueg@donlingold.com
Michael Shelbourn	Barrick	mshelbourn@barrick.com
Richard Williams	Novagold	richard.willams@novagold.com
Clint Logue	BGC	clogue@bgcengineering.ca
Adrian Wightman	BGC	awightman@bgcengineering.ca
Jack Seto	BGC	jseto@bgcengineering.ca
Vinod Garga	BGC	vgarga@bgcengineering.ca
Iain Bruce	BGC	ibruce@bgcengineering.ca
Jon Isaacs	AECOM/URS	jon.isaacs@urs.com
Bob Bachus	Geosyntec	rbachus@geosyntec.com
Dan Johnson	Tetra Tech	dan.johnson@tetratech.com
Jeff Bruno	State of Alaska – DNR/OPMP	jeff.bruno@alaska.gov
Charlie Cobb	State of Alaska – Dam Safety	charles.cobb@alaska.gov
Pete McGee (by phone)	State of Alaska – DEC	william.mcgee@alaska.gov
Carolyn Curley (by phone)	State of Alaska – DNR	carolyn.curley@alaska.gov
Jeff Foley	Calista	jfoley@calistacorp.com
Rachel Klein	TKC	rlk@kuskokwim.com
Nancy Darigo	URS	nancy.darigo@urs.com
Kris Fabian	URS	kristof.fabian@urs.com
Dan Neuffer	SRK	dneuffer@srk.com
Bill Jeffress	SRK	bjeffress@srk.com
Maritz Rykaart	SRK	mrykaart@srk.com
Patty McGrath	SRK	pmcgrath@srk.com

A summary of the workshop objectives, scope and approach was distributed to all participants as part of an information package issued prior to the workshop. At the beginning of the workshop, the FMEA approach was reviewed with the group. It was noted that the FMEA process uses very coarse categories of "likelihood" that do not attempt to distinguish between very low probability levels. Participants agreed that, because the dams are still in the design process, the focus should be on identifying as many risks as possible rather than precisely quantifying each one. The slides used by the facilitator to introduce the session and review the approach are included in Appendix A1.

BGC staff then presented information on the TSF dam, investigations to date, and the state of design as presented in the Feasibility Study Update 2. In a later session, BGC provided a similar presentation on the Snow Gulch Reservoir. It was noted that the Snow Gulch Reservoir Dam is in a much earlier stage of design, and that other variants are still under consideration. The BGC presentations are also included in Appendix A1, and selected drawings in Appendix A2.

After the introductory presentation on each facility, participants were asked to create lists of risks related to its construction and operation period, its closure and post-closure period, and a hypothetical premature closure. Groups of participants then reviewed each list and identified key risks for discussion and evaluation. The selection of risks to carry through further discussion was left up to the participant groups, with only the guidance that examples should be selected to cover the range of risks.

The process of evaluating each risk began with a single participant describing how the risk would lead to a failure scenario. The facilitator assisted in reducing the scenario to a short sentence that was entered into a risk register used for recording the workshop results, and then evaluating the scenario using a set of risk rating tools:

- A consequence-severity matrix that rates the severity of different types of adverse consequence;
- A likelihood chart used to rate the probability of the scenario and negative consequences being realized;
- A confidence level table used to express the level of certainty in the consequence and likelihood ratings; and
- A risk matrix used to summarize consequence severity and likelihood in terms of risk level.

The risk rating tools that were used in the FMEA workshop are provided in Appendix B.

In total, over 80 scenarios were assessed. For each scenario, discussion continued until a consensus was reached. The final position of the scenario on the consequence-severity, likelihood and confidence scales was then recorded in the risk register. After the first few risk scenarios had been analyzed, it became evident that there was a close correlation between scenario types and the most important consequence categories. Subsequent evaluations focused on only those categories that generated the highest severity ratings.

4 FMEA Results and Limitations

The risk register for the TSF is provided in Appendix C. The risk register for the Snow Gulch Reservoir is presented in Appendix D. Each appendix also includes summary risk matrices showing where each scenario plotted in terms of likelihood and consequence severity.

It is worth noting again that the process used in the workshop was intended to capture as many risks as possible, rather than precisely characterizing each one. Therefore the results shown in the risk registers should be treated with appropriate caution. Specifically, there are certain to be other failure modes or at least ones that differ in some detail from those assessed, and many of the likelihood or severity designations could arguably be shifted to an adjacent box. However, despite those weaknesses, the results do accurately reflect what an informed and reasonable group of people, representing many perspectives, found to be the significant risks associated with the current designs for these two facilities.

Furthermore, it bears repeating that the early stage FMEA reviewed designs presented in the project documents available at the time, and many of the risks will be addressed or modified in subsequent stages of design. This was particularly the case for Snow Gulch Reservoir, for which the available documents represented an even earlier stage of design.

5 Closure

At the close of the workshop, SRK prepared a first draft of this report for review, initially by Donlin Gold and subsequently by all other participants. Review comments were reviewed and addressed in the final version.

It was also noted that participants in the workshop will use the results in different ways. The project team, for example, might use them to assign priorities to future investigation and design efforts. Other participants might use the results to inform their contributions to the project environmental review. SRK has deliberately avoided trying to summarize the results from any particular perspective, preferring instead to let the results produced by the entire group stand on their own merits. SRK cautions against using any of the scenarios or risk ratings without considering the full context and limitations of the workshop process.

This report, Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop, was prepared by:

SRK Consulting (Canada) Inc.

ORIGINAL SIGNED BY

Daryl Hockley, PEng, PE
Corporate Consultant

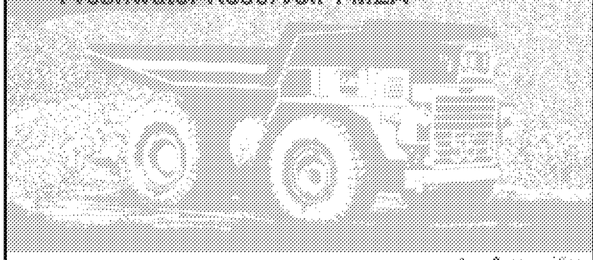
and reviewed by

ORIGINAL SIGNED BY

Cam Scott, PEng
Principal Consultant

Appendix A1 – PowerPoint Presentations

FMEA Facilitation Presentation



Donlin Creek Tailings Storage Facility & Snow Gulch Freshwater Reservoir FMEA

Workshop Overview

- Introductions & Objectives
- Assessment Methodology
- Tailings Storage Facility
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis
- Snow Gulch Freshwater Reservoir
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis

Introductions & Objectives

- Introductions

Introductions & Objectives

- Objective
  - Identify and evaluate all significant risks associated with the TSF Dam and Snow Gulch Reservoir Dam with a view to ensuring that these risks are addressed in current and future design …

Assessment Methodology

- ISO 31000 "Risk – effect of uncertainty on objectives"
  1. An effect is a deviation from the expected -- positive and/or negative
  2. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and processes)
  3. Risk is often characterized by reference to potential events (2.19) and consequences, or a combination of these.
  4. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstance) and the associated likelihood of occurrence.
  5. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood

Assessment Methodology

- Risk assessment – "Overall process of risk identification, risk analysis and risk evaluation"
  - Risk identification – process of finding, recognizing and describing risks
  - Risk analysis – process to comprehend the nature of risk and determine the level of risk
  - Risk evaluation – process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable

Assessment Methodology

- Consequence-Severity methods
  - Failure Mode and Effect Analysis (FMEA)
  - Failure Mode Effect and Criticality Assessment (FMECA)
- Common characteristics
  - Assesses the likelihood of a risk coming to fruition, and the severity of its consequences
  - Considers consequences in many categories

Consequence Severity Scale

Consequence Category	Severity Descriptions				
	Very Low	Minor	Moderate	Major	Critical
1. Environmental Impact	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Traditional Use	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. Regulatory Impact	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. Consequence Costs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. Community/ Media/ Reputation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. Human Health and Safety	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Likelihood Scale

Likelihood	Frequency Descriptor 1	Frequency Descriptor 2	Probability of occurrence over twenty years
Almost Certain	Happens often	High frequency (more than once every 5 years)	95%
Likely	Could easily happen	Event does occur, has a history, once every 15 years	75%
Possible	Could happen and has happened elsewhere	Occurs once every 40 years	40%
Unlikely	Hasn't happened yet but could	Occurs once every 200 years	10%
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years	2%

Risk Matrix

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain	Moderate	Moderately High	High	[illegible]	[illegible]
Likely	Moderate	Moderate	Moderately High	High	[illegible]
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Confidence Level

Confidence Level	Description
Low	Do not have confidence in the estimate or ability to control during operations.
Medium	Have some confidence in the estimate or ability to control during operations, conceptual level analyses.
High	Have lots of confidence in the estimate or ability to control during operations: detailed analyses following a high standard of care.

Assessment Methodology

- Brainstorming

Assessment Methodology

- Brainstorming
- Scenarios
  1. One individual proposes a **scenario**
     - Consequence severity
     - Likelihood
     - Risk matrix
  2. We debate any of the above steps and if necessary change the rating
  3. The we record the result on the risk register

Assessment Methodology

- Risk register for TSF
  - Construction & Operation
  - Planned Closure and Post-Closure
  - Premature Closure
- Risk register for Snow Gulch FWRD
  - Construction & Operation
  - Planned Closure and Post-Closure
  - Premature Closure

Next Steps

- SRK will prepare a Draft FMEA Report
  - Introduction
  - Limitations
  - Workshop methodology
  - Risk register
- Review by participants
  - Comments appended to report
- Revised FMEA Report
- Further stages of design and review →

Questions?

Workshop Overview

- Introductions & Objectives ✓
- Assessment Methodology ✓
- Tailings Storage Facility
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis
- Snow Gulch Freshwater Reservoir
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis

Workshop Overview

- Introductions & Objectives ✓
- Assessment Methodology ✓
- Tailings Storage Facility
  - Design Presentation ✓
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis
- Snow Gulch Freshwater Reservoir
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis

Workshop Overview

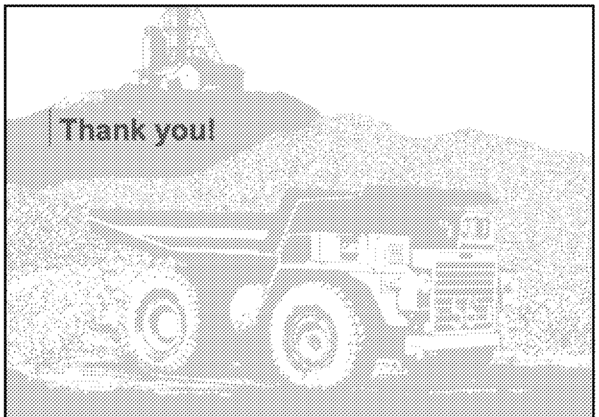
- Introductions & Objectives ✓
- Assessment Methodology ✓
- Tailings Storage Facility
  - Design Presentation ✓
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis
- Snow Gulch Freshwater Reservoir
  - Design Presentation
  - Failure Mode Brainstorming ✓
  - Failure Mode & Effects Analysis

Next Steps

- Draft report
  - Introduction
  - Limitations
  - Workshop methodology
  - Risk register
- Review by participants
  - Comments appended to report
- FMEA Report
- Further stages of design and review →

Feedback Comments

21 of XX



Project Overview Presentation

Donlin Gold Project

BGC

BGC Engineering Inc.

DONLIN GOLD

Donlin Gold FMEA Workshop

Project Summary
December 2-3, 2014

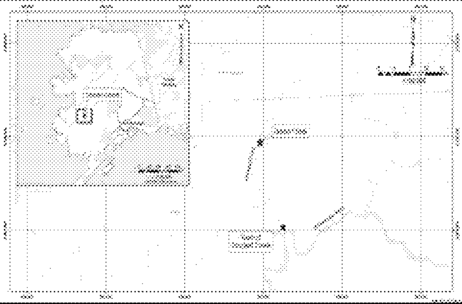
Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Project Location



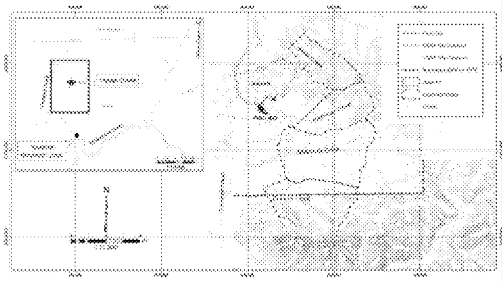
Alaska, USA

Donlin Gold Project

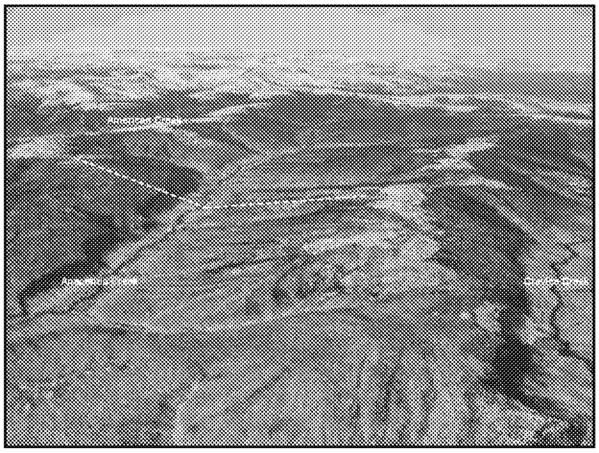
BGC

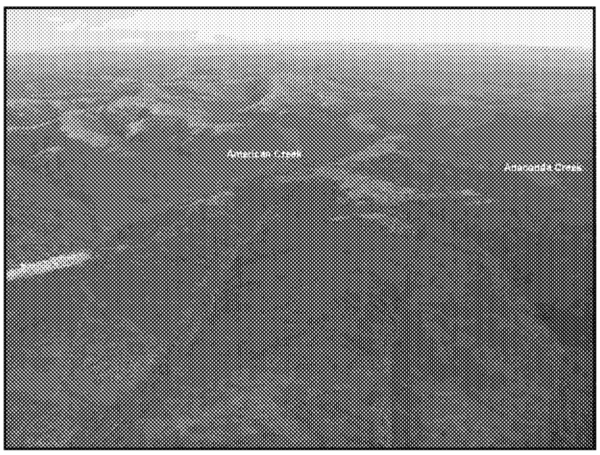
DONLIN GOLD

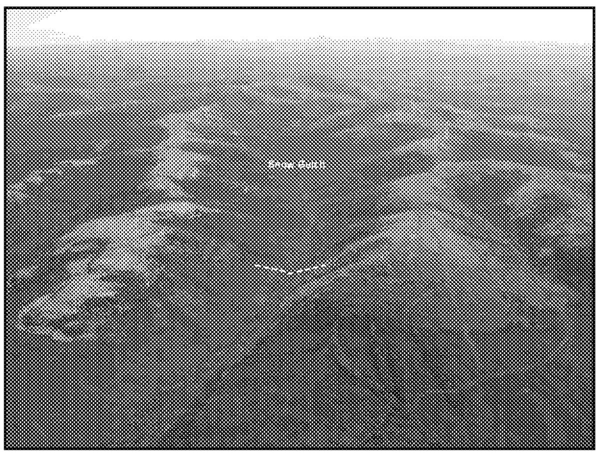
Site Layout



Alaska, USA





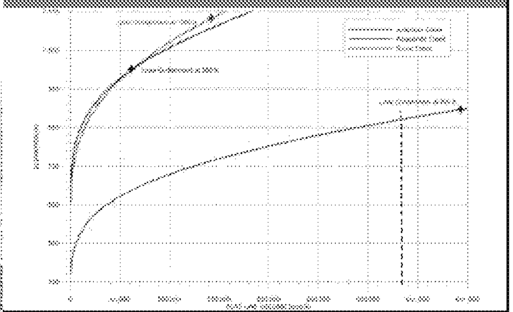


Donlin Gold Project

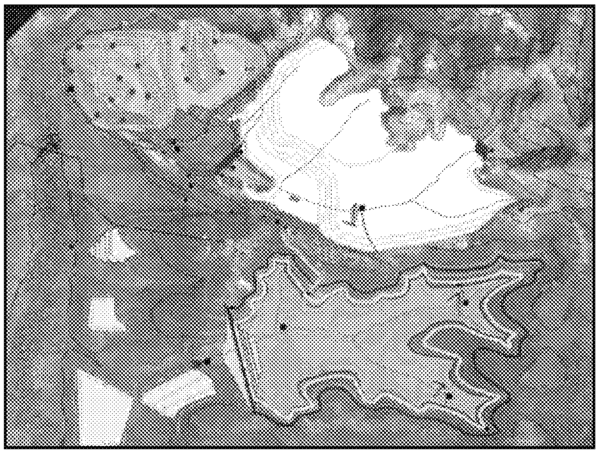
BGC

DONLIN GOLD

Volume Elevation Curves: Anaconda, American, Snow Creeks



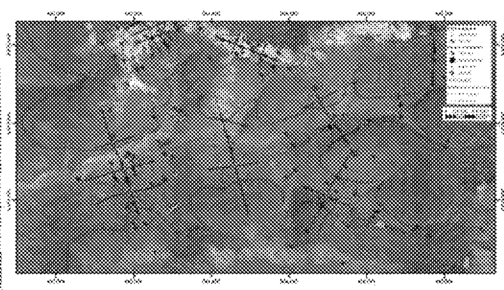
Alaska, USA



Donlin Creek Gold Project

BGC

TSF Site Investigation Program



Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Bedrock Geology

- Geology consists of flysch sequence of sedimentary units of the Cretaceous Kuskokwim Group;
- Sedimentary units comprise interbedded greywackes, siltstones, and shale;
- Series of anticlines/synclines perpendicular to regional compression;
- Intruded by late Cretaceous to early Tertiary felsic intrusives comprising porphyritic rhyodacite and rhyolite with mafic dykes and sills.
- Bedrock heavily fractured/pervious.

Alaska, USA

Donlin Gold Project

BGC

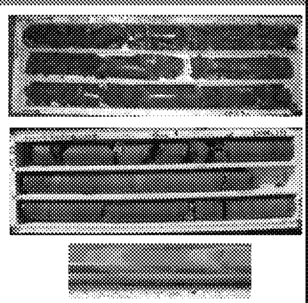
DONLIN GOLD

Bedrock Geology

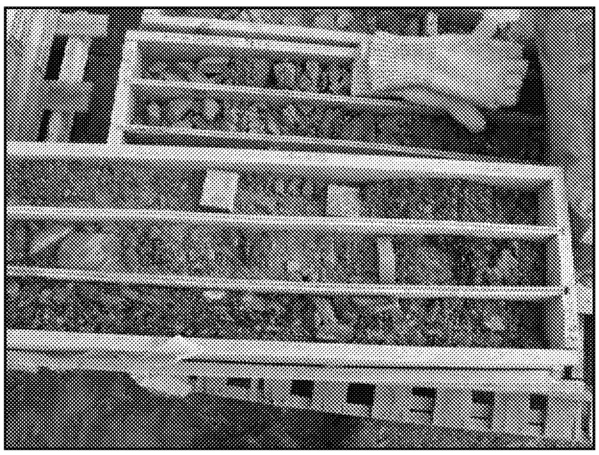
Siltstone
- Dark grey
- Fine grained
- Bedded
- In general weak to medium strong
- UCS_{avg} = 7,900 psi (55 MPa)

Greywacke
- Light grey
- Medium grained
- Well graded
- In general medium strong
- UCS_{avg} = 9,100 psi (63 MPa)

Interbedded Greywacke/Siltstone
- UCS_{avg} = 5,800 psi (40 MPa)



Alaska, USA



Donlin Gold Project

BGC

DONLIN GOLD

Surficial Geology

Surficial geology comprises colluvial, fluvial (Holocene and Tertiary), and aeolian deposits with overlying organic deposits;
- Approx. 20 ft thick in valley bottom
- Approx. 7 ft thick at higher elevations

Alaska, USA

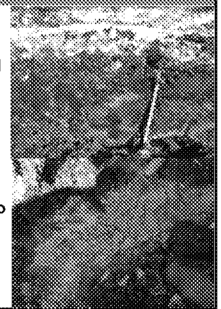
Donlin Gold Project

BGC

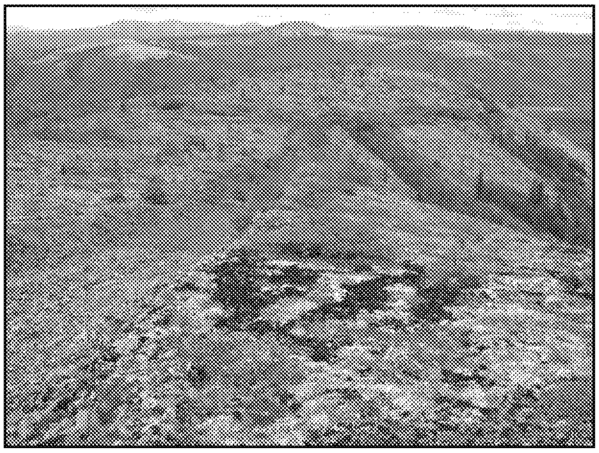
DONLIN GOLD

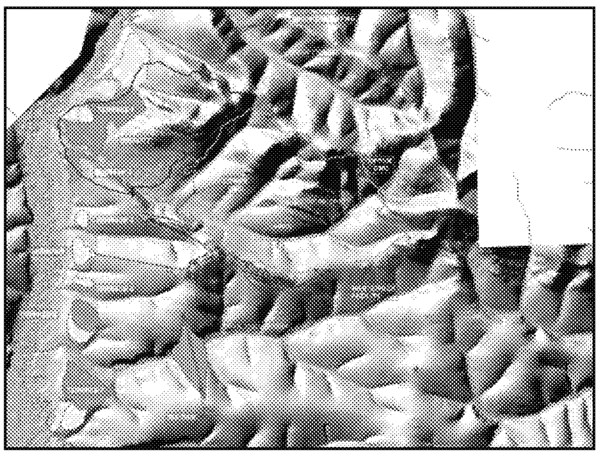
Permafrost

Site is located in the sporadic discontinuous permafrost zone:
- Where present, typically confined to lower portions of valley, in overburden with organic cover, and is warm (31.6 °F)
- Thickness generally less than 20 ft, can be up to 105 ft
- Low ground ice content
  - typically <1 to 2% segregated ice, with discrete zones of 5 to 10%



Alaska, USA



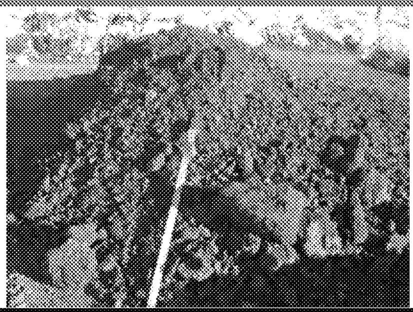


Donlin Gold Project

BGC

DONLIN GOLD

Liner Bedding (Terrace Gravels)



Alaska, USA

BGC TSF and Snow Gulch Presentation

Donlin Gold Project

BGC

BGC Engineering Inc.

DONLIN GOLD

Donlin Gold FMEA Workshop

Tailings Storage Facility and Snow Gulch

December 2-3, 2014

Alaska, USA

Donlin Gold Project

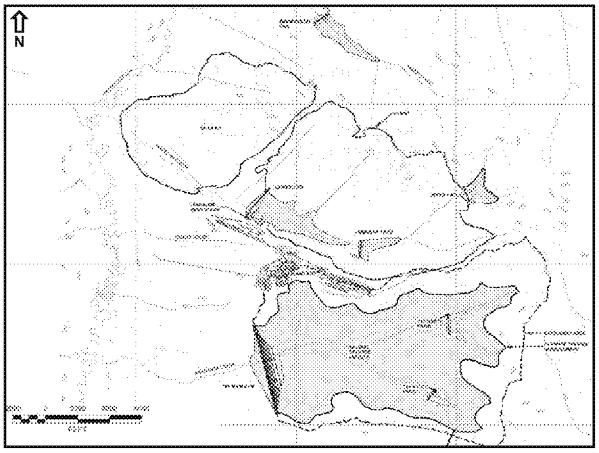
BGC

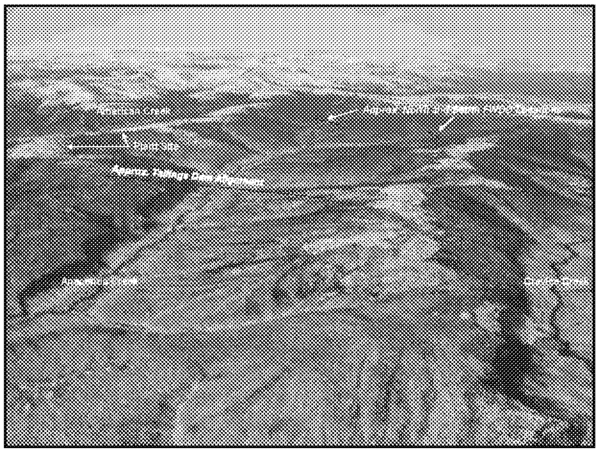
DONLIN GOLD

Dams - Summary

- Seven dams under DNR jurisdiction :
  - Lower Contact Water Dam
  - Upper Contact Water Dam
  - American Freshwater Diversion Dam
  - Snow Gulch Freshwater Dam
  - North and South TSF Freshwater Dams
  - Anaconda TSF Dam
- Class I Dams:
  - Snow Gulch Freshwater Dam
  - Anaconda TSF Dam

Alaska, USA



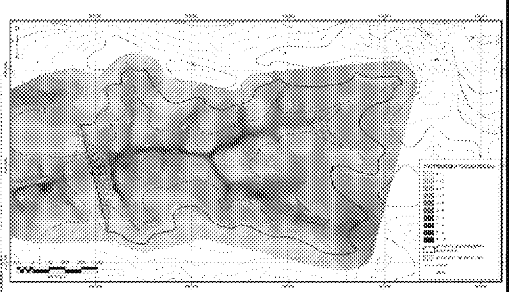


Donlin Gold Project

BGC

DONLIN GOLD

Overburden Thickness (in metres)



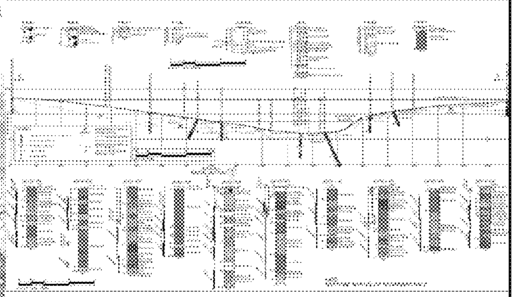
Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Cross-Section along Centerline



Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Dam Design Criteria

- Meet or exceed requirements in:
  - Alaska DNR Dam Safety Guidelines
  - USBR, USACE, FEMA, ICOLD, CDA
- Design Earthquake
  - MCE
    - Deterministic MCE – 0.36g from Magnitude 7.8
    - Probabilistic MCE – 0.44g from 10,000-year event

Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Dam Design Criteria

- Static Safety Factors
  - Steady state = 1.5
  - End of Construction = 1.3
  - Temporary excavation and rapid drawdown = 1.3
- Seismic Deformation
  - Max. deformation of half filter thickness = 5'

Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Tailings Storage Facility Design – Storage Capacity

- During Operations, store LOM tailings plus:
  - Starter - 1 yr Tailings (12,400 ac-ft)
  - Ultimate Tailings (334,000 ac-ft))
  - IDF = 200-yr Snowmelt + 24-hr PMP (6,700 ac-ft)
  - Ultimate Operating Pond (24,000 ac-ft)
  - Freeboard (above maximum stored flood)
- Freeboard calculated as the maximum of:
  - 3 ft above maximum beach elevation;
  - Wave run-up and wind set-up above maximum stored flood elevation; or
  - Maximum seismic settlement at upstream face of dam plus 3 ft above operating pond

Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Tailings Storage Facility Design – Storage Capacity

- Wave action on stored flood dominates freeboard
  - Ultimate dam crest : 841 ft
- Closure spillway to pass PMF
  - Sill elevation: 834 ft
  - Details to be worked out at next stage of design as timing of closure cover and pond size has a significant impact on the layout of the spillway.
- Dam downstream face flattened to 3H:1V at closure.
- Saddle elevation at 850 ft on south east side of Anaconda.

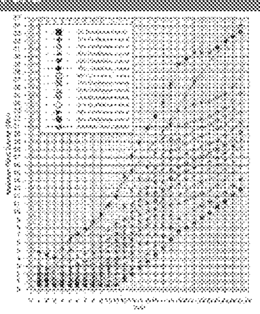
Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

TSF Operating Pond



Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Tailings Dam Design – Summary

Name	Height /Crest El.	Length	Dam Volume (Mcu.yds)	Storage Requirements (acre-ft)				Outlet
				Tailings	Operating Pond	Flood	Total	
Starter	202 ft/ 571 ft	2,310 ft	3.7	12,400	1,700	6,700	20,800	Reclaim barge pumps
Ultimate	471 ft/ 841 ft	5,863 ft	43.1	334,000	16,200	6,700	356,900	Emergency spillway; PMP capacity. Reclaim pumps.

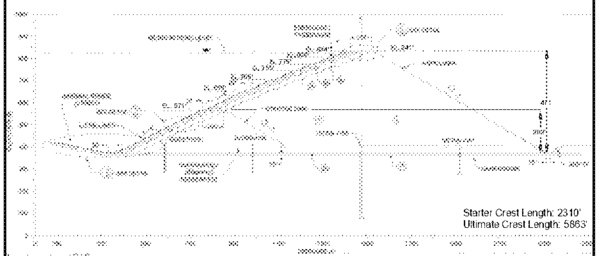
Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

TSF Design – Dam Section



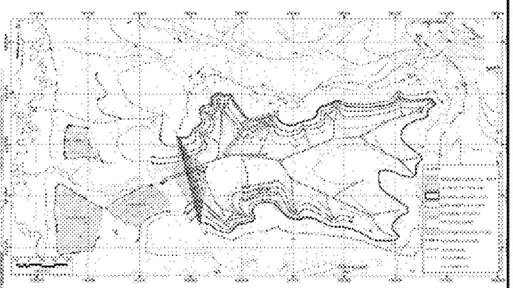
Alaska, USA

Donlin Gold Project

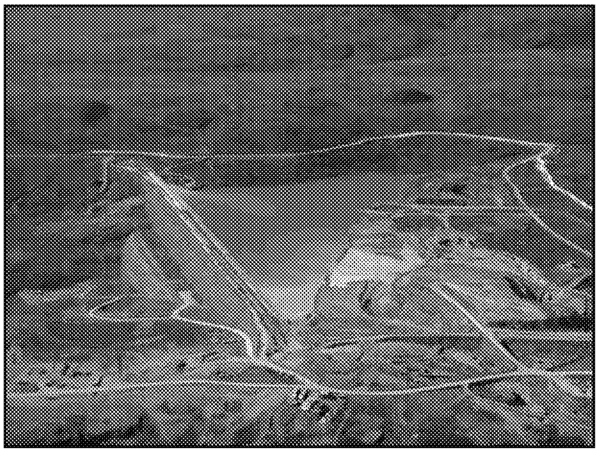
BGC

DONLIN GOLD

Underdrain Configuration (FSUii)



Alaska, USA

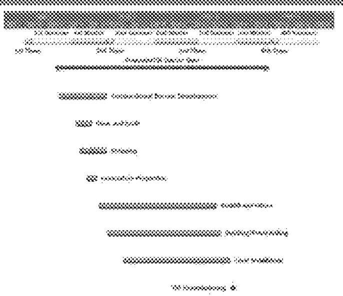


Donlin Gold Project

BGC

DONLIN GOLD

Construction Execution



Alaska, USA

Donlin Gold Project

BGC

DONLIN GOLD

Construction Execution - Seasonal Constraints

- Preparatory works (borrow areas)
- Winter 1 - Nov - March
  - Prepare overburden stockpiles
  - Construction water handling (sumps, ditches, berms)
  - Clearing, grubbing, stripping dam footprints underdrain
  - Construction of starter dam and diversion dams
  - Construction of seepage recovery system if required for construction water management
  - Construction of diversion ditches/access roads.

Alaska, USA

Donlin Gold Project

BGC

Construction Execution - continued

DONLIN GOLD

- <u>Summer 1</u> - May to October
  - Continue construction of dams
  - Continue/complete diversion ditches.
- <u>Winter 2</u>
  - Clearing, grubbing, stripping of impoundment and reclaim causeway
  - Complete underdrain
  - Liner bedding placed and compacted
  - Complete seepage recovery system
  - Continue/complete construction of dams and diversion ditches.

Alaska, USA

Donlin Gold Project

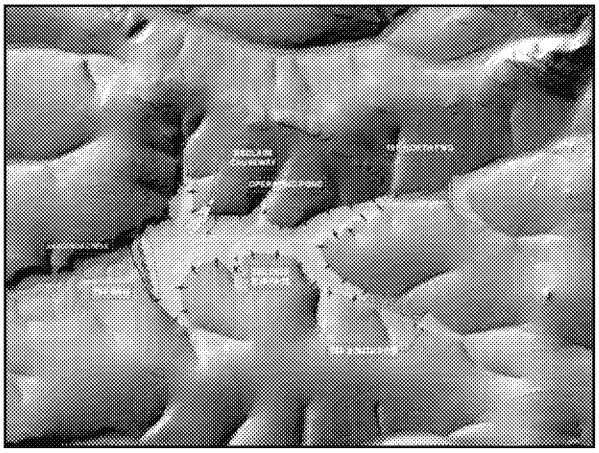
BGC

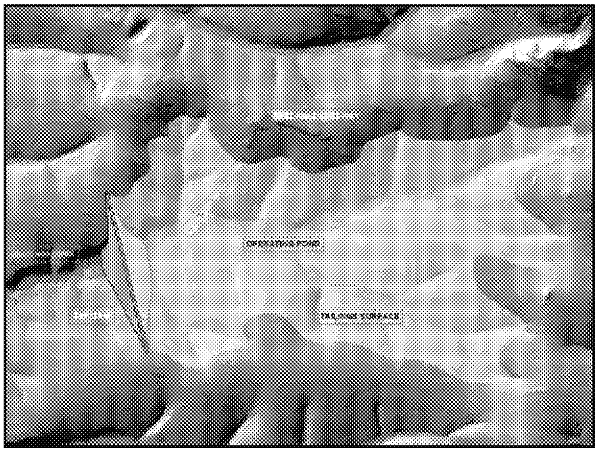
Construction Execution - continued

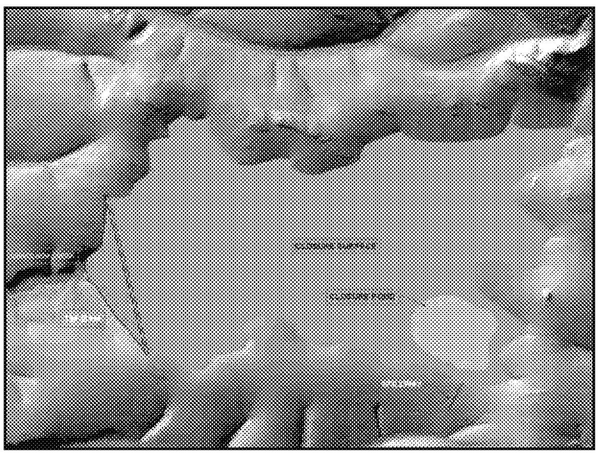
DONLIN GOLD

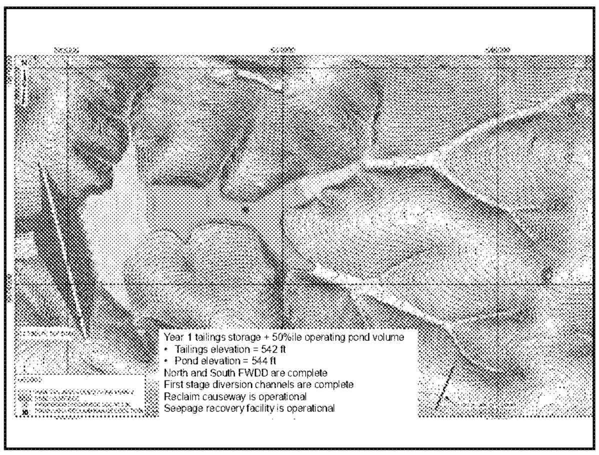
- <u>Summer 2</u>
  - Re-grade and re-compact/proof-roll liner bedding as required
  - Complete construction of all elements
  - Place liner
- Portion of the valley above bottom 80 ft of the creek can be constructed independent of season

Alaska, USA



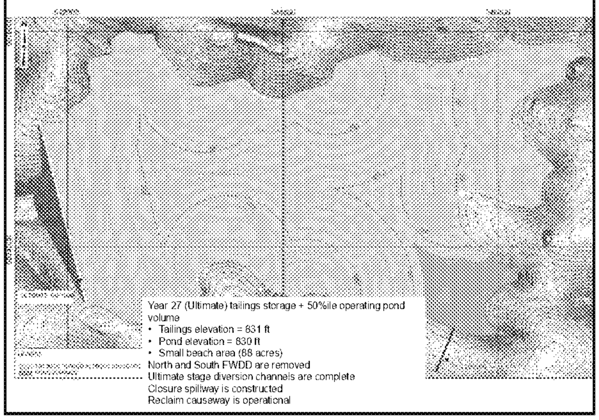


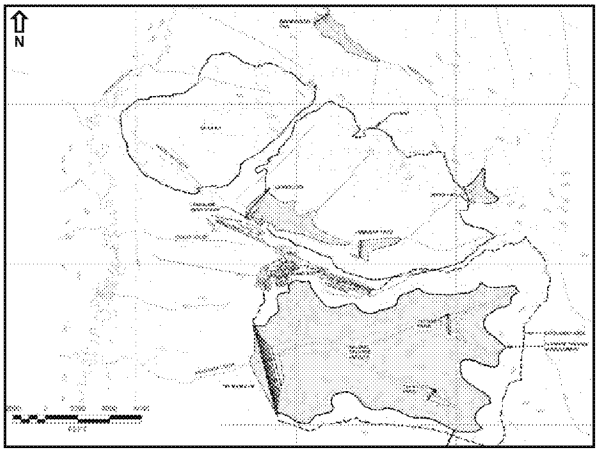


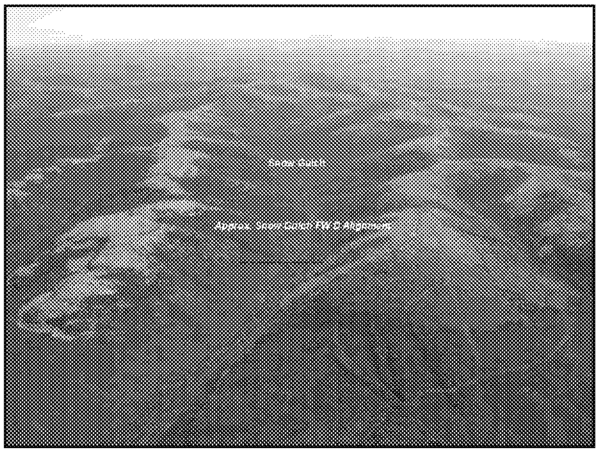


ED_014329A_00000114-00257

Year 3 Layout – Maximum Beach Development





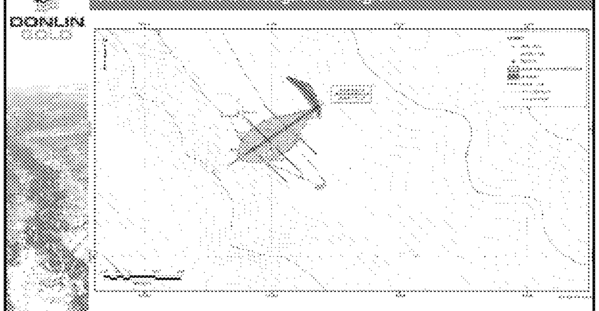


Donlin Gold Project

BGC

DONLIN GOLD

Snow Gulch Site Investigation Program



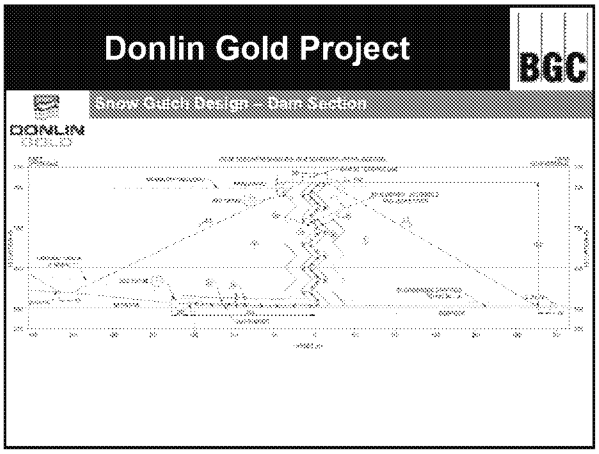
Alaska, USA

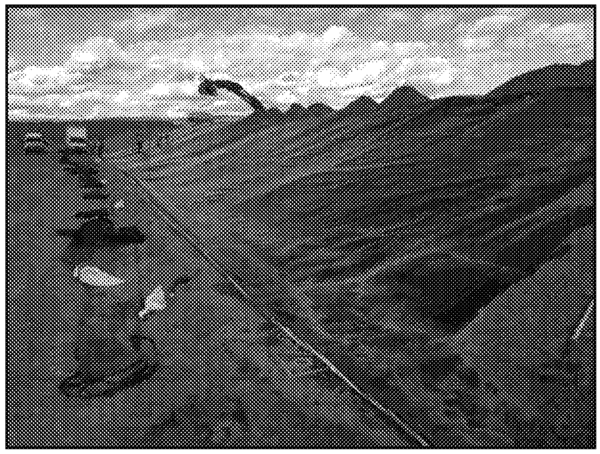
Donlin Gold Project

BGC

Water Dams Design – Summary

Name	Height /Crest El.	Length	Dam Volume (M cu.yds)	Max. Operating Pond	Storage Requirements	Outlet
Lower CWD	150' / 673'	2303'	1.5	811 acre-ft	PMP + max operating pond. (7,150 acre-ft)	Operating pumps to Upper CWD.
Upper CWD	189' / 1114'	1024'	1.1	2,432 acre-ft	Lower CWD outflow.	Emergency spillway; PMP capacity. Operating pumps.
American FWDD	95' / 781'	1142'	0.4	868 acre-ft	Stays full, supplies FW to plant	Operating spillway; 1:100 year capacity
Snow Gulch FWDD	154' / 756'	1211'	1.04	3,243 acre-ft	Stays full, supplies FW to plant.	Operating spillway; PMP capacity
North FWDD	74' / 856'	1080'	0.3	478 acre-ft	100-yr snowmelt	Pump to diversion channels, emergency spillway
South FWDD	68' / 858'	858'	0.14	211 acre-ft	100-yr snowmelt	Pump to diversion channels, emergency spillway


Donlin Gold Project
BGC
Snow Gulch Design – Dam Section
DONLIN
GOLD



Appendix A2 – Selected Drawings

Ex. 4 CBI Copyright

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

X:\Projects\0011111\Workspace\20110429

SCALE:	1:40,000
DATE:	JULY 22, 2011
DRAWN:	SMR, LL, GLT, JVC, IL
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	CL

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN

TITLE: DONLIN CREEK SITE LAYOUT

PROJECT No.:	DWG No.:	REV.:
0011-111	01	

DWG TO BE READ WITH BGC REPORT TITLED "DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II, TAILINGS STORAGE FACILITY DESIGN" DATED JULY 22, 2011

Ex. 4 CBI Copyright

X:\Projects\0011111\Workspace\20110429_RE

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	AS SHOWN
DATE:	JULY 22, 2011
DRAWN:	GCB
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	SAH

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN

TITLE: GEOLOGICAL CROSS SECTION TAILINGS DAM - ANACONDA CREEK

PROJECT No.:	DWG No.:	REV.:
0011-111	04	

DWG TO BE READ WITH BGC REPORT TITLED "DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN" DATED JULY 22, 2011

Ex. 4 CBI Copyright

X:\Projects\0011111\Workspace\20110429_R6

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	AS SHOWN
DATE:	JULY 22, 2011
DRAWN:	GCB
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	SAH

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN

TITLE: ULTIMATE TAILINGS DAM SCHEMATIC CROSS-SECTION

PROJECT No.:	DWG No.:	REV.:
0011-111	11	

DWG TO BE READ WITH BGC REPORT TITLED " DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN " DATED JULY 22, 2011

Ex. 4 CBI Copyright

X:\Projects\0011111\Workspace\20110429_RE

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:25,000
DATE:	JULY 22, 2011
DRAWN:	SMR, LL, GLT, JVC
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	CL

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN

TITLE: ANACONDA CREEK TAILINGS STORAGE FACILITY ULTIMATE LAYOUT

PROJECT No.:	DWG No.:	REV.:
0011-111	09	

DWG TO BE READ WITH BGC REPORT TITLED "DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN" DATED JULY 22, 2011

Ex. 4 CBI Copyright

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:5,000
DATE:	JULY 22, 2011
DRAWN:	SMR, MIB, GLT, JVC
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	CL

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK FEASIBILITY STUDY UPDATE II
AMERICAN CREEK AND SNOW GULCH
CONTACT AND FRESH WATER DAM DESIGN

TITLE: SNOW GULCH FRESH WATER DAM LAYOUT

PROJECT No.:	DWG No.:	REV.:
0011-111	03	

X:\Projects\0011111\Workspace\20110429_RE

DWG TO BE READ WITH BGC REPORT TITLED "DONLIN CREEK FEASIBILITY STUDY UPDATE II, AMERICAN CREEK AND SNOW GULCH CONTACT AND FRESH WATER DAM DESIGN" DATED JULY 22, 2011

Ex. 4 CBI Copyright

Y:\Projects\0011\111\Workspace\20110429

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	AS SHOWN
DATE:	JULY 22, 2011
DRAWN:	GCB
DESIGNED:	CL
CHECKED:	VKG
APPROVED:	SAH

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DONLIN CREEK LLC

PROJECT: DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II AMERICAN CREEK AND SNOW GULCH CONTACT AND FRESH WATER DAM DESIGN

TITLE: SNOW GULCH FRESH WATER DAM SCHEMATIC CROSS-SECTION

PROJECT No.:	DWG No.:	REV.:
0011-111	7	

DWG TO BE READ WITH BGC REPORT TITLED " DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II AMERICAN CREEK AND SNOW GULCH CONTACT AND FRESH WATER DAM DESIGN " DATED JULY 22, 2011

Appendix B – FMEA Tools

Donlin Gold TSF and Snow Gulch Early Stage FMEA Workshop – Risk Rating Tools

This appendix presents the tools that form the basis of the risk rating method used in the FMEA workshop held on December 2 and 3, 2014.

In general, risk rating methods used in FMEA's are expert-based rather than analytical. In other words, assessments of consequence severity (how bad could it be?) and likelihood (could it really happen?) are based on the consensus of expert opinion rather than on detailed calculation of probabilities. This approach allows a much wider range of risks to be considered as efficiently as possible. Differences of opinion about consequence severity and likelihood are tracked and, where they prove to be significant to a design decision, more rigorous analysis is a common follow-up requirement.

The proposed process begins with a participant describing a failure scenario. With guidance from the facilitator, the wording of the failure mode and effect are crystallized for evaluation with the risk rating tools. These tools comprise three tables and a risk matrix; shown in Tables 1 through 4 below.

Table 1 presents six categories of consequences along with severity ratings ranging from 'Very Low' to 'Critical'. For each category, the table includes narrative descriptions of the types of negative outcomes that would be typical for each severity rating; during the workshop these descriptions help participants determine the appropriate severity rating to be assigned to each failure scenario.

Table 2 presents descriptors used to aid participants in assigning a 'Likelihood' rating for each scenario. The 'Likelihood' rating reflects the participants' view of the probability that both the failure mode and consequence (from the previous chart) will be realized. The 'Likelihood Terminology' table consists of one column containing likelihood ratings that range from 'Very Unlikely' to 'Almost Certain', along with four other columns which give examples to guide the selection of the appropriate rating.

Table 3 presents the 'Confidence Levels' used to reflect the participants' confidence in the consequence and probability categories selected for each scenario.

Table 4 presents the 'Risk Matrix' which assigns a risk rating (and color) to each combination of likelihood (from Table 1, identified by row on Table 4) and severity (from Table 2, identified by column on Table 4). The risks range from low (in green) to moderate (in yellow) to moderately high (in pale orange) to high (in dark orange) to very high (in red).

Table 1: Consequence-Severity Matrix

	Severity Descriptors				
Consequence Categories	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
2. Traditional Use	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
3. Regulatory Impact	Informal advice from a regulatory agency.	Technical/Administrative non-compliance with permit, approval or regulatory requirement.	Breach of regulations, permits, or approvals (e.g. one-day violation of discharge limits).	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits).	Major breach of regulation – willful violation.
4. Consequence Costs	< $100,000	$100,000 – $1 Million	$1 – $5 Million	$5 – $25 Million	> $25 Million
5. Community/ Media/ Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local/regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
6. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Single fatality and/or severe irreversible disability or impairment to one or more people.	Multiple fatalities.

Table 2: Likelihood Terminology

Likelihood	Frequency Descriptor 1	Frequency Descriptor 2	Probability of occurrence over twenty years	Probability of occurrence in any one year
Almost Certain	Happens often	High frequency (more than once every 5 years)	98%	17.8%
Likely	Could easily happen	Event does occur, has a history, once every 15 years	75%	6.7%
Possible	Could happen and has happened elsewhere	Occurs once every 40 years	40%	2.5%
Unlikely	Hasn't happened yet but could	Occurs once every 200 years	10%	0.5%
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years	< 2%	0.1%

Table 3: FMEA Confidence Levels

Confidence Level	Description
Low	Do not have confidence in the estimate or ability to control during operations.
Medium	Have some confidence in the estimate or ability to control during operations; conceptual level analyses.
High	Have lots of confidence in the estimate or ability to control during operations; detailed analyses following a high standard of care.

Table 4: Risk Matrix

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Appendix C – TSF Risk Register

TSF Construction and Operation

Likelihood \ Consequence Severity	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely		23C, 23R, 36C, 38C, 42C			
Possible		14C, 33C, 43C	7C, 9E, 25C, 31C, 4C, 35C, 38R, 39C	9C, 21C, 49R	
Unlikely		32C	8E, 14E, 18C, 19C, 32C, 47C, 38T	1E, 1C, 1T, 1R, 8T, 46E, 46R, 46M, 47R	1M
Very Unlikely			20E, 26E	1H, 44C, 49E	2E, 2H, 4E, 24C, 24H, 37E, 37H

TSF Closure & Post-Closure

Likelihood \ Consequence Severity	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely		41C			
Possible			27C, 29C, 40E	40R, 40T, 49R	
Unlikely		30C		5C, 16C, 30T, 30E, 45C	22C
Very Unlikely				12C, 48E	11E, 11H

TSF Premature Closure

Likelihood \ Consequence Severity	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible		28C	10E	3E, 15C, 17C	
Unlikely				10T, 13R	
Very Unlikely				6E	

Consequence Types

- **E** Environmental Impact
- **T** Traditional Use
- **R** Regulatory Impact
- **C** Consequence Costs
- **M** Community/Media/Reputation
- **H** Human Health and Safety

Risk Level

- Low
- Moderate
- Moderately High
- High
- Very High

	TSF							
	Scenario	Project Stage	Consequence Type	Consequence Severity	Likelihood Descriptor	Risk Rating Descriptive	Confidence Level	NOTES
1	Downstream failure of dam due to material variability results in partial breach and loss of material (2 million cu.m.) that reaches Crooked Creek.	Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	M	Rock fill material is currently uncharacterized. Crooked Creek is valuable ecosystem. Scenario assumed to occur near end of mine life with full pond, so that even a partial breach leads to significant tailings release.
1		Const. & Op	Com/Media/Rep.	Critical	Unlikely	Moderately High	M	
1		Const. & Op	Cons. Costs	Major	Unlikely	Moderately High	M	
1		Const. & Op	Human H&S	Major	Very Unlikely	Moderate	M	
1		Const. & Op	Trad. Use	Major	Unlikely	Moderately High	M	
1		Const. & Op	Reg. Imp.	Major	Unlikely	Moderately High	M	
2	Poor QA/QC during construction of filter/liner materials results in a leak and ultimately a piping failure and a catastrophic breach	Const. & Op	Env. Imp.	Critical	Very Unlikely	Moderately High	M	Some participants thought likelihood could be "Unlikely". Poor QA has happened elsewhere, but this mode requires both filter and liner to fail.
2		Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	M	Any complete breach of dam will also have very significant costs
3	Excessive water accumulation with no spillway in place leads to overtopping and loss of water	Prem.Cl.	Env. Imp.	Major	Possible	High	L	Net water balance is positive, but liklelihood is "Possible" because it requires assuming no mitigation for 1-2 years
4	Liner rupture directly above the underdrain leads to sinkhole and outflow of tailings through underdrain	Const. & Op	Env. Imp.	Critical	Unlikely	Moderately High	M	Loss of 20% of tailings would be enough to lead to critical consequences
5	Deformation along a fault in the valley leads to rupture of liner resulting in increased seepage and water treatment costs	Cl. & P.Cl.	Cons. Costs	Major	Unlikely	Moderately High	L	
6	Excessive water accumulation with no spillway in place leads to controled unauthorized discharge	Prem.Cl.	Env. Imp.	Major	Very Unlikely	Moderate	M	"Very Unlikely" because water would be sent to pit
7	Clogging of underdrain due to excessive weight/chemical reactions leading to build-up of pore pressures resulting in liner damage, construction delay and need for repairs.	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	
8	Weather event exceeds design criteria leading to overtopping and discharge of contaminated water (but no breach)	Const. & Op	Env. Imp.	Moderate	Unlikely	Moderate	M	Extreme event assumed to occur during normal operations. Hydrological analysis suggests "Very Unlikely" but could be limiations to data.
8		Const. & Op	Trad. Use	Major	Unlikely	Moderately High	M	"Major" consequence would be the temporary loss of fishing
9	Pond levels builds up over time, reducing available freeboard and then a extreme weather event occurs leading to overtopping resulting in discharge of contaminated water	Const. & Op	Env. Imp.	Moderate	Possible	Moderately High	M	Extreme event assumed to be preceded by period of abnormal operations, with no response by operator
9		Const. & Op	Cons. Costs	Major	Possible	High	L	Mitigation costs for early raise of dam, pumping to pit, treating for discharge
10	Cover construction delays leading dust releases to the surrounding lands for a 3-4 years.	Prem.Cl.	Trad. Use	Major	Unlikely	Moderately High	M	Assumes no dust control measures in place during 3-4 years of surface flooding
11	Spillway blockage by ice and snow leads to overtopping and breach of the dam	Cl. & P.Cl.	Env. Imp.	Critical	Very Unlikely	Moderately High	M	Spillway is at Crevice Creek but failure would be at Main Dam
11		Cl. & P.Cl.	Human H&S	Critical	Very Unlikely	Moderately High	M	
12	Long-term degradation of the liner leads to increased seepage and water treatment costs	Cl. & P.Cl.	Cons. Costs	Major	Very Unlikely	Moderate	M	Scenario refers to liner on the dam face, and possible degradation due to slope creep on the 1.7H:1V slope. Underlying material could be metal leaching.
13	Waste rock on dam face remains uncovered leading to contaminated run-off	Prem.Cl.	Reg. Imp.	Major	Unlikely	Moderately High	M	Assumes dam face remains uncovered and rock leaches metals

	TSF							
	Scenario	Project Stage	Consequence		Likelihood	Risk Rating	Confidence Level	NOTES
			Type	Severity	Descriptor	Descriptive		
14	Liner damage due to an ice sheet results in increased seepage that exceeds seepage recovery system and poor water quality downstream	Const. & Op	Env. Imp.	Moderate	Unlikely	Moderate	L	Could be "Minor" if change to seepage volume is small
14		Const. & Op	Cons. Costs	Minor	Possible	Moderate	L	
15	Spillway can't be constructed into Crevice Creek resulting in additional pumping costs	Prem.Cl.	Cons. Costs	Major	Possible	High	L	Assumes inadequate financial security in place, or requirement to tunnel
16	Pond water quality does not improve and pumping is required over the very long term	Cl. & P.Cl.	Cons. Costs	Major	Unlikely	Moderately High	M	
17	Lack of grading by spigotting leads to additional costs for mechanical grading for closure cover	Prem.Cl.	Cons. Costs	Major	Possible	High	L	assumes inadequate bonding in place
18	Differential settlement due to thawing of previously unidentified permafrost leading to liner damage and increased seepage and water treatment costs	Const. & Op	Cons. Costs	Moderate	Unlikely	Moderate	M	
19	Differential settlement of alluvial soils under loading leads to liner damage and increased seepage and water treatment costs	Const. & Op	Cons. Costs	Moderate	Unlikely	Moderate	M	
20	Rupture of the liner leads to piping of native materials into the underdrain and release of tailings and formation of a sinkhole over time	Const. & Op	Env. Imp.	Moderate	Very Unlikely	Low	M	Liner rupture is not dierctly above underdrain, so this requires piping of through alluvial soils
21	Missing construction window due to strike/weather delay/etc. results in one year delay	Const. & Op	Cons. Costs	Major	Possible	High	L	Current schedule includes a 12 month storage contingency (except for Starter Dam). Costs very uncertain.
22	Earthquake results in tailings liquefaction and cover damage resulting in need for repairs	Cl. & P.Cl.	Cons. Costs	Critical	Unlikely	Moderately High	M	Depends on liquefaction potential of the tailings, but final slope will be 1-2% so damage could be less.
23	Failure of surface water diversion (localized instability/glaciation/blockage) etc. results in need for repairs of diversion ditches	Const. & Op	Reg. Imp.	Minor	Likely	Moderate	M	Technical non-compliance, but no risk of discharging the water
23		Const. & Op	Cons. Costs	Minor	Likely	Moderate	M	
24	Mass wasting failure at the abutment (landslide) occurs following construction results in catastropic failure of the dam and release of tailings	Const. & Op	Cons. Costs	Critical	Very Unlikely	Moderately High	M	
		Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	M	
25	Landslide within impoundment results in damage of the liner and need for repairs.	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	Some participants thought this secnario is "Unlikely". The consequence sevrity classification assumes that the liner damage is accessible for repair.
26	Mass wasting failure in the saddle area (spillway not yet built) leads to uncontrolled release of water and tailings	Const. & Op	Env. Imp.	Moderate	Very Unlikely	Low	M	
27	Landslide into spillway plugs the spillway results in need for repairs	Cl. & P.Cl.	Cons. Costs	Moderate	Possible	Moderately High	M	
28	Degradation of the liner due to environmental exposure leads to seepage into the underdrain	Prem.Cl.	Cons. Costs	Minor	Possible	Moderate	M	
29	Ice entrainment in tailings results in delay in construction of closure cover	Cl. & P.Cl.	Cons. Costs	Moderate	Possible	Moderately High	L	Other consequences dicussed at length, but design is based on total containment of water so little sensitivity to ice
30	Soil cover over the downstream slope of the dam at closure performs worse than expected leads to downstream water quality issues	Cl. & P.Cl.	Cons. Costs	Minor	Unlikely	Low	M	
30		Cl. & P.Cl.	Trad. Use	Major	Unlikely	Moderately High	M	
30		Cl. & P.Cl.	Env. Imp.	Major	Unlikely	Moderately High	M	
31	Temporary closure leads to need to store extra water and results in need to raise dam sooner and higher ultimate crest height.	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	
32	Thermal expansion of liner causes folding and covering of folds with tailings leads to defects and increased seepage		Cons. Costs	Minor	Unlikely	Low	M	

	TSF							
	Scenario	Project Stage	Consequence		Likelihood	Risk Rating	Confidence Level	NOTES
			Type	Severity	Descriptor	Descriptive		
33	Construction related damage to the liner results in increased seepage	Const. & Op	Cons. Costs	Minor	Possible	Moderate	M	Construction defects are "Almost Certain" but much less likely to lead to significant consequences
34	Consolidation/settlment of tailings results in rupture of horizontal seam leading to increased seepage	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	
35	Gas bubble developing under the liner (impoundment area) leads to need for repairs	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	Stripping of organics prior to liner placement should limit methane generation
36	Wildlife causes damage to liner leads to need for repairs	Const. & Op	Cons. Costs	Minor	Likely	Moderate	H	Moose or bear
37	Deep-seated failure of the dam foundation due to undiscovered conditions leads to catastrophic failure of the dam	Const. & Op	Env. Imp.	Critical	Very Unlikely	Moderately High	M	Any complete breach of dam will also have very significant costs
37		Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	M	
38	During the first year of starter dam operation, exceedance of regulatory freeboard requirements	Const. & Op	Reg. Imp.	Moderate	Possible	Moderately High	M	
39	Barge capsizes resulting in liner damage leading to need for repairs	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	
40	Failure of custodial care leads to exceedance of seepage pumpback system and uncontrolled release of contaminated water	Cl. & P.Cl.	Env. Imp.	Moderate	Possible	Moderately High	M	3-5 days until the seepage system overtops. Assumption is that it is not mitigated, leding to significant releases over long period
40		Cl. & P.Cl.	Reg. Imp.	Major	Possible	High	M	
40		Cl. & P.Cl.	Trad. Use	Major	Possible	High	M	
41	Excessive vegetation in the spillway results in blockage of spillway and need for maintenance	Cl. & P.Cl.	Cons. Costs	Minor	Likely	Moderate	M	
42	Snow sliding on exposed liner causes damage	Const. & Op	Cons. Costs	Minor	Likely	Moderate	M	
43	Inability to anchor HDPE liner on the downtream face of the dam due to wind	Const. & Op	Cons. Costs	Minor	Possible	Moderate	M	
44	Reclaim water quality not meeting ore processing requirements	Const. & Op	Cons. Costs	Major	Very Unlikely	Moderate	H	
45	Irregular consolidation leading to pond against the dam face	Cl. & P.Cl.	Cons. Costs	Major	Unlikely	Moderately High	L	
46	Emergency discharge for any reason (pumping into creek)	Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	M	
46		Const. & Op	Reg. Imp.	Major	Unlikely	Moderately High	M	
46		Const. & Op	Com/Media/Rep.	Major	Unlikely	Moderately High	M	
47	Clogging of the underdrain at seepage recovery system leads to pore water pressure build-up in the dam and shallow slope failure and damage to the seepage recovery system	Const. & Op	Cons. Costs	Moderate	Unlikely	Moderate	M	
47		Const. & Op	Reg. Imp.	Major	Unlikely	Moderately High	M	
48	Degradation of rockfill leads to slope failure of the dam face and release of tailings (2 million cubic meters)	Cl. & P.Cl.	Env. Imp.	Major	Very Unlikely	Moderate	M	
49	Seepage recovery system does not function resulting in multi-day discharge into creek	Const. & Op	Reg. Imp.	Major	Possible	High	M	

Appendix D – Snow Gulch Risk Register

Snow Gulch Construction & Operation

Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely		3C	14M		
Possible		26R	6C, 19E, 19T, 23C	8C, 10C, 34E	34H
Unlikely	27R	28R, 29C	2C, 17E, 17R, 17M, 18R, 27E, 27M, 28E	7E, 11E, 12E, 13C, 17C, 21E, 26C, 30M, 31E, 32E, 33E	7H, 11H, 12H, 21H, 31H, 32H, 33H
Very Unlikely				1E, 1R, 20E, 25E	1H, 4H, 5H, 20H, 25H

Consequence Severity

Snow Gulch Closure & Post-Closure

Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible		22E	16E, 24C		
Unlikely					
Very Unlikely					

Consequence Severity

Snow Gulch Premature Closure

Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible					15H
Unlikely					
Very Unlikely					

Consequence Severity

Consequence Types
- **E** Environmental Impact
- **T** Traditional Use
- **R** Regulatory Impact
- **C** Consequence Costs
- **M** Community/Media/Reputation
- **H** Human Health and Safety

Risk Level
- Low
- Moderate
- Moderately High
- High
- Very High

	Snow Gulch Reservoir							
	Scenario	Project Stage	Consequence Type	Consequence Severity	Likelihood Descriptor	Risk Rating Descriptive	Confidence Level	NOTES/ MITIGATIONS
1	Landslide blocks the spillway leading to overtopping and breach of the dam	Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	L	
1		Const. & Op	Env. Imp.	Major	Very Unlikely	Moderate	L	Erosion of spawning gravels
1		Const. & Op	Reg. Imp.	Major	Very Unlikely	Moderate	L	Violation of fisheries protection and dam safety rules
2	Landslide blocks the spillway leading to need for repairs	Const. & Op	Cons. Costs	Moderate	Unlikely	Moderate	L	Small watershed and small flows limit likelihood of more serious consequences
3	Ice glaciation blocks the spillway leading to need for maintenance and increased pumping costs	Const. & Op	Cons. Costs	Minor	Likely	Moderate	M	
4	Intentional blockage of the spillway due to operator misunderstanding and a large rainfall event leads to overtopping	Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	M	
5	Landslide occurs above or under the abutment leads to lowering of the crest height and overtopping of the dam	Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	L	Limited field investigation to date, only four boreholes
6	Thawing of ice lenses leads to internal erosion in the abutments results in need for grouting	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	L	Thick ice lenses are unlikely to be missed but even thin ones could initiate piping
7	High seepage gradient at the upstream liner embedment leads to piping and failure of the dam (complete breach)	Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	M	
7		Const. & Op	Human H&S	Critical	Unlikely	Moderately High	M	
8	High seepage gradient at the upstream liner embedment leads to piping, drawdown of dam, and loss of use of reservoir	Const. & Op	Cons. Costs	Major	Possible	High	M	Loss of stored water could lead to production halt
9	Local community or landowner requests permanent dam and lack of long-term oversight or maintenance ultimately results in a breach (due to any of the failure modes noted above)	Cl. & P.Cl.	Env. Imp.	Major	Unlikely	Moderately High	L	Dam is not being designed for very long term use, and is in fact designed to be removed after mine usage ends. But there are examples eslewhere of dams being re-purposed without adequate review of the initial design assumptions.
9		Cl. & P.Cl.	Human H&S	Critical	Unlikely	Moderately High	M	
10	Foundation materials are more permeable than expected, resulting in need for grouting during construction or remedial grouting following construction.	Const. & Op	Cons. Costs	Major	Possible	High	L	Uncertain if grouting would work, and possible that reservoir would need to be abandoned
11	Landslide into reservoir leads to large wave, overtopping of the dam, down-cutting and a complete breach	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	L	
11		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	L	
12	Internal erosion beneath the liner leads to loss of support causing a liner failure, and complete breach of dam	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	L	Some participants thought that likelihood should be"possible", given lack of filters on drains in current design
12		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	L	
13	Steep liner slopes lead to poor construction quality and result in insufficient storage for mill operations	Const. & Op	Cons. Costs	Major	Unlikely	Moderately High	M	
14	Higher than expected seepage results in concern from local community and regulators.	Const. & Op	Com/Media/Rep.	Moderate	Likely	Moderately High	M	"Moderate" because of negative press coverage
15	Inadequate routine dam inspections do not detect slowly developing problems that lead to a breach failure of the dam	Prem.Cl.	Human H&S	Critical	Possible	High	M	
16	Sediment deposition during operations and erosion following decommissioning result in excessive sediment loading downstream	Cl. & P.Cl.	Env. Imp.	Moderate	Possible	Moderately High	M	

	Snow Gulch Reservoir							
	Scenario	Project Stage	Consequence Type	Consequence Severity	Likelihood Descriptor	Risk Rating Descriptive	Confidence Level	NOTES/ MITIGATIONS
17	Extreme flood event in early stage of construction results in overtopping and dam failure	Const. & Op	Env. Imp.	Moderate	Unlikely	Moderate	L	
17		Const. & Op	Reg. Imp.	Moderate	Unlikely	Moderate	L	
17		Const. & Op	Cons. Costs	Major	Unlikely	Moderately High	L	
17		Const. & Op	Com/Media/Rep.	Moderate	Unlikely	Moderate	L	
18	Reservoir water quality compromised by waste rock, dust, etc. resulting in poor water quality and inability to discharge	Const. & Op	Reg. Imp.	Moderate	Unlikely	Moderate	L	
19	Degradation of seepage water quality caused by ARD/ML issues with dam fill materials.	Const. & Op	Env. Imp.	Moderate	Possible	Moderately High	L	"Moderate" assumes metal release during spawning season
19		Const. & Op	Trad. Use	Moderate	Possible	Moderately High	L	
20	Seismic event larger than design results in breach of the dam	Const. & Op	Env. Imp.	Major	Very Unlikely	Moderate	M	
20		Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	M	
21	Motion along an undetected fault beneath the dam results in rupture of the liner and failure of the dam	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	L	
21		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	L	
22	Repeated drawdown and recharge leading to mass wasting failure in reservoir leading to discharge of suspended sediments	Cl. & P.Cl.	Env. Imp.	Minor	Possible	Moderate	M	
23	Sinking of the barge leads to need for replacement of the barge	Const. & Op	Cons. Costs	Moderate	Possible	Moderately High	M	
24	Repeated drawdown leads to mass wasting in the reservoir resulting in increased reclamation requirements on the failed slopes	Cl. & P.Cl.	Cons. Costs	Moderate	Possible	Moderately High	L	
25	Permeability of the rockfill is less than design leading to increased pore water pressures and a slope failure through crest resulting in a breach	Const. & Op	Env. Imp.	Major	Very Unlikely	Moderate	L	
25		Const. & Op	Human H&S	Critical	Very Unlikely	Moderately High	L	
26	Rockfill shell degrades leading to excessive deformations and need for increased maintenance	Const. & Op	Cons. Costs	Major	Unlikely	Moderately High	L	
26		Const. & Op	Reg. Imp.	Minor	Possible	Moderate	L	Technical non-compliance
27	Emergency discharge for any reason (pumping into creek)	Const. & Op	Env. Imp.	Moderate	Unlikely	Moderate	M	Erosion damage, but stream is already impacted by placer mining
27		Const. & Op	Reg. Imp.	Very Low	Unlikely	Low	M	ADEC would allow discharge assuming water quality is good
27		Const. & Op	Com/Media/Rep.	Moderate	Unlikely	Moderate	M	Any discharge from a mining-related dam, even clean water, could generate negative press
28	Poor rock quality leads to erosion and downcutting of the spillway	Const. & Op	Env. Imp.	Moderate	Unlikely	Moderate	M	
29	Emergency discharge is required (for any reason) and the normal service pumps are unable to meet needed discharge rate	Const. & Op	Cons. Costs	Minor	Unlikely	Low	M	Cost for pumps and piping

	Snow Gulch Reservoir							
	Scenario	Project Stage	Consequence		Likelihood	Risk Rating	Confidence Level	NOTES/ MITIGATIONS
			Type	Severity	Descriptor	Descriptive		
30	Upstream blanket length is undersized leading to high seepage gradient resulting in excessive seepage flow	Const. & Op	Com/Media/Rep.	Major	Unlikely	Moderately High	M	
31	Poor quality rockfill and high seepage gradient leads to piping and failure of the dam.	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	L	Rock fill currently uncharacterized
31		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	L	
32	Limited understanding of hydrology results in undersized spillay and overtopping of dam during extreme storm events.	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	M	
32		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	M	
33	High seepage gradient through the foundation leads to a piping failure through fractures and highly weathered bedrock and a breach	Const. & Op	Human H&S	Critical	Unlikely	Moderately High	L	Confidence is low due to the fact that only limited drilling has been completed for the current stage of design
33		Const. & Op	Env. Imp.	Major	Unlikely	Moderately High	L	
34	Lack of detailed site investigations will lead to deficiencies in the dam design resulting in a breach	Const. & Op	Human H&S	Critical	Possible	High	M	Scenario assumes that further investigations will not be completed
34		Const. & Op	Env. Imp.	Major	Possible	High	M	